Proceedings of the 2010 Trinational Pacific Sardine Forum

L. Flostrand, J. Detering, and J. Schweigert

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9R 6N7

2011

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2970

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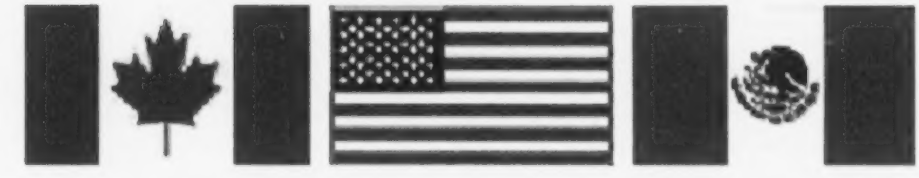
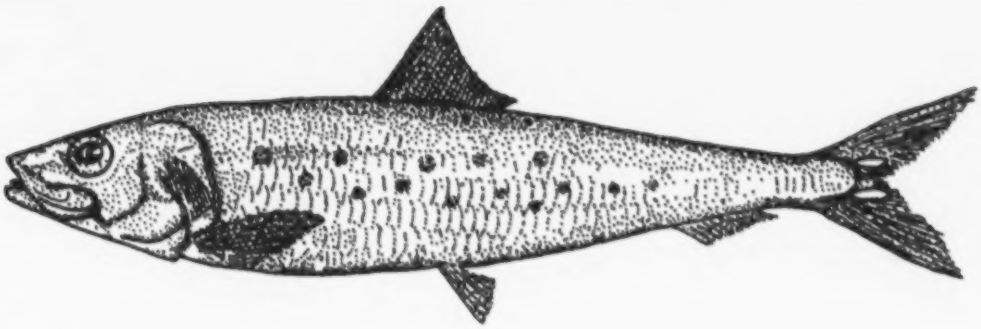
PROCEEDINGS OF THE 2010 TRINATIONAL PACIFIC SARDINE FORUM





by

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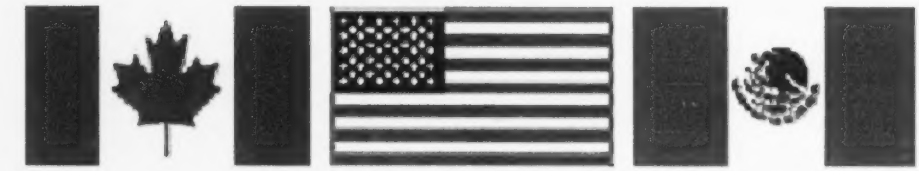

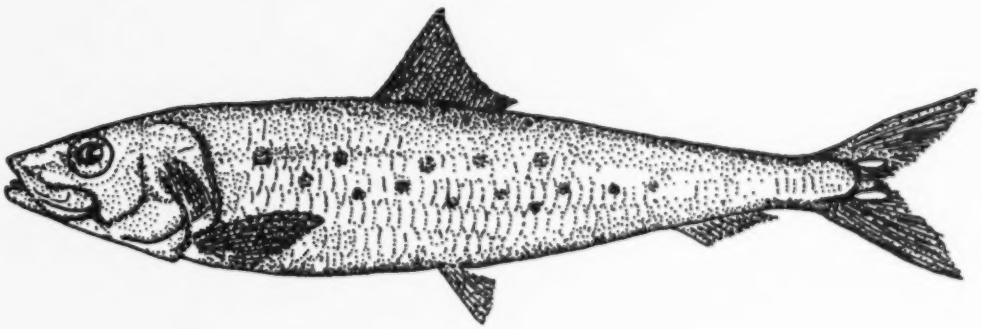

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ABSTRACT

Flostrand, L., Detering. J., and Schweigert, J. 2011. Proceedings of the 2010 Trinational Pacific Sardine Forum. Can. Manuscr. Rep. Fish. Aquatic. Sci. 2970: vii + 55 p.

The 11th annual Trinational Pacific sardine forum was held in November of 2010 in Victoria, British Columbia, bringing together scientists, fishery managers and fishing industry representatives from Mexico, the United States and Canada to share information and research findings related to the sardine resource off the west coast of North America. There were 23 oral presentations given and 19 abstracts were submitted, which are included in the proceedings. The proceedings also include regional sardine fishing reports representing recent (e.g. 2009-2010) fishing activity in Mexico, the United States and Canada and regional sardine biomass reports representing recent abundance trends in the United States and Canada. Notes from working groups are also included pertaining to: 1) research projects, methods and results related to characterising stock status, 2) information related to characterising stock composition, structure and migration, and 3) industry trends, research interests and concerns.

RESUMÉ

Flostrand, L., Detering. J., and Schweigert, J. 2011. Proceedings of the 2010 Trinational Pacific Sardine Forum. Can. Manuscr. Rep. Fish. Aquatic. Sci. 2970: vii + 55 p.

Le 11e forum trinational annuel sur la sardine du Pacifique s'est tenu en novembre 2010 à Victoria, en Colombie-Britannique, rassemblant des scientifiques, des responsables des pêches et des représentants de l'industrie de la pêche du Mexique, des États-Unis et du Canada pour partager de l'information et des résultats de recherche relativement aux ressources de sardines au large de la côte ouest de l'Amérique du Nord. En tout, 23 présentations étaient au programme et 19 résumés ont été soumis; vous trouverez ces derniers dans le présent compte-rendu. Le compte-rendu comprend également des rapports régionaux sur la pêche à la sardine faisant état des récentes activités de pêche (par ex. 2009-2010) au Mexique, aux États-Unis et au Canada, ainsi que des rapports régionaux sur la biomasse de la sardine illustrant les tendances récentes en terme d'abondance aux États-Unis et au Canada. Vous y trouverez également les notes des groupes de travail se rapportant aux sujets suivants : 1) projets de recherche, méthodes de qualification de l'état des stocks ainsi que leurs résultats; 2) données sur la qualification de la composition, de la structure et de la migration des stocks; 3) tendances de l'industrie, intérêts pour la recherche et préoccupations.

GROUP PHOTOGRAPH

Participants of the 2010 Trinational Pacific Sardine Forum

Harbour Towers, Victoria, British Columbia, Canada.
November 16-18, 2010

Back row from the left: Darin Macey, Don (Louie) Savourd, Sam McClatchie, Robert Emmet, Nancy Lo, Jake Schweigert, Rebecca Baldwin, Cynthia Johnston, Juan Zwolinski, Motomitsu Takahashi, Kerry Griffin, David Demer

Middle row from the left: Samuel F. Herrick Jr, John Lenic, Tim Ward, Bill Bird, Rashid Sumailla, Mitch Ponak, Alena Pribyl, Charlie Cootes, Mike Okoniewski, Jackie Detering, John Ferguson, Greg Krutzikowsky, Gordon (Sandy) McFarlane, Kym Jacobson, Mike Hill, Don Pepper, Lisa Mijacika, Randy Webb, Jim Ruzicka, Sandy Argue

Front row from the left: Felipe Hurtado-Ferro, Beverly Macewicz, Andres Cisneros, Russ Vetter, Kevin Miller, Brent Melan, Ryan Kapp, Dennis Chalmers, Linnea Flostrand

INTRODUCTION

The 11th annual Trinational Pacific Sardine Forum (commonly referred to as the Trinational Sardine Forum or TSF) was held at the Harbour Towers Hotel in Victoria, British Columbia on November 16-17, 2010, followed by an ecosystem modeling workshop on November 18, 2010. This was the second time that the forum was held in Canada. The previous time was on November 1-3, 2006, where it was held in Vancouver (Hrabok et al. 2007). More than 50 participants were in attendance at the 2011 forum, representing scientists, governments, industry, and academia. Similar to the 2006 forum, the 2011 forum was made possible through funding contributions from Fisheries and Oceans Canada (DFO), the Provincial Government of British Columbia and the Canadian Pacific Sardine Association. Information on the agenda, participants, organising committees and commonly used acronyms is provided in the appendices.

As an Executive Committee member of the TSF, Dr. Nancy Lo (South West Fisheries Center, NOAA) welcomed participants and provided background and history of the TSF. Since its inception in 2000, the TSF mission has been to firstly improve the stock assessment of sardine through collaboration between Canada, the United States and Mexico. Secondly, the TSF aims to follow sardine specific industry trends and issues. The TSF also seeks to further our collective understanding of the role of sardine in the ecosystem. Dr. Lo encouraged participants to have a fruitful and productive meeting.

Special guest Mr. Barron Carswell, Director of Oceans & Marine Fisheries, Province of British Columbia delivered opening remarks. Mr. Carswell took time to reflect on the dynamic history of the sardine population and its connections to economic development in the province of British Columbia. He applauded the ecosystem workshop as a timely project to be undertaken.

Further opening remarks were delivered by special guest Dr. Laura Brown, Director of Marine Ecosystems Aquaculture Division, Science Branch of the Department of Fisheries and Oceans Canada. Dr. Brown noted that globalization, climate change and its effect on migratory trends pose new challenges to the assessment and management of the sardine resource; a species which plays a pivotal role in the ecosystem. Dr. Brown viewed the TSF as a wonderful medium and a unique opportunity for collaboration between science, academia and industry.

Over the course of the two day TSF, a total of 23 oral presentations related to sardines were shared. The topics of these presentations ranged from regional fishery catch and management reports, regional biomass stock status information, physiology, parasitology, migration trends, reproduction, stock structure, oceanography, economics, and various survey methods (including trawl, acoustics and aerial).

On the afternoon of November 17, 2010, the group divided into three concurrent workgroups sessions; WG1: Regional Biomass, WG2: Stock Structure, Age Structure and Adult Sampling, WG3: Industry Trends and Issues. Summaries of working group discussion are found in subsequent sections of these proceedings.

The workshop on modeling ecological linkages of Pacific sardine in the California current system was held on November 18, 2010. The workshop was convened by Jake Schweigert and Sandy McFarlane. University of British Columbia Ph.D. candidate Andrés Cisneros-Montemayor introduced the Ecopath with Ecosim (EwE) modelling tool and provided a demonstration of the software. Proceedings of the ecosystem modelling workshop are presented in an appendix.

The 12th annual Trinational Sardine Forum will take place in La Jolla (San Diego), California on December 8-9, 2011. An ageing workshop will take place on December 10, 2011.

Introduction reference

Hrabok, C. Schweigert, J.F., Chalmers, D., and Pepper, D. 2007. Proceedings of the 2006 Trinational Pacific sardine forum. Can. Manuscr. Rep. Fish. Aquat. Sci. 2815: v+74p.

ACKNOWLEDGEMENTS

Thanks to all who participated in the TSF; your contributed presentations, discussions, and comments played an essential role in the forum! Planning and coordinating the TSF required time and effort from many individuals, but a special thanks to Nancy Lo for assisting with the program and to Bernie White and Sean MacConnachie for assisting with the logistics. The Department of Fisheries and Oceans Canada, the Province of British Columbia, and the Canadian Sardine Association provided financial support for the meeting. Local seafood served at the group dinner reception was provided by *Finest At Sea Seafood.*

REGIONAL SARDINE FISHERY REPORTS

MEXICO

Bahia Magdalena, 2009-2010

Roberto Félix-Uraga, Felipe Neri Melo-Barrera, Casimiro Quiñonez-Velázquez and Víctor Daniel Hernández Valdez. Centro Interdisciplinario de Ciencias Marinas, Departamento de Pesquerías y Biología Marina, Becarios COFAA y EDI

The monthly catch of sardine in Magdalena Bay in 2009 showed the typical pattern in this fishing area, where the maximum of occurs during May to August (Fig. 1). It is important to comment that by September 2nd and 3rd of this year, Bahia Magdalena was hit by the hurricane Ximena and after this event the sardine catch went down dramatically to the grade of disappearing completely in November and December and continued during the first four months of the following year for the Pacific sardine. This hurricane affected the infrastructure, plants, piers, etc, as the availability of the Pacific sardine.

During 2009, 530 fishing trips were carried out and 45,106 mt of small pelagic fishes were caught. Catch of the Pacific sardine (*Sardinops sagax)* was 36,338 mt, representing 92.8% of total catch (Fig 2). Other species landed included *Opisthonema* sp (3.7%), *Cetengraulis mysticetus* (2.9%), *Etrumeus teres* (0.2%) and *Scomber japonicus* (0.3%).

Pacific sardine was caught throughout 2009 (except in November & December), although 81% of landings were from May to August and 73.6% of fishing trips were carried out at this time. Sizes of the Pacific sardine ranged between 121-200 mm SL (Fig. 4). Only 33.2% of sardines caught were above the minimum legal size (150 mm SL). Five age groups (0 to 4) were found, although age group 1 was the most abundant (78.4%; Fig. 5). During January to August 2010, 21,061 mt of small pelagic fishes has been caught in 316 fishing trips (Fig. 5). Pacific sardine practically disappeared of Bahia Magdalena during ten months (September 2009-June 2010).

Pacific sardine catch was 8,172 mt and represented only 38.8% of total landings (Fig. 6). Others species caught in these months of 2010 were *Opisthonema spp* with 4,960 mt (23.5%), 6,682 mt (31.7%) of *Scomber japonicus*, 387 mt (1.8%) of *Cetengraulis mysticetus*, and 860 mt of a mix of species (4.1%). Biological samples of Pacific sardine taken during 2010 haven't still been analyzed.

Yearly landings of small pelagic fishes in Bahia Magdalena were close to 50,000 mt during 2000-2010. Nevertheless, the fishery has shown a declining trend during last five years, as well as the fishing effort which depends of the availability of the resource. Total landings in 2006 were 58,237 mt whereas in 2010 (January to August) decreased to 21,061 mt (Fig. 7).

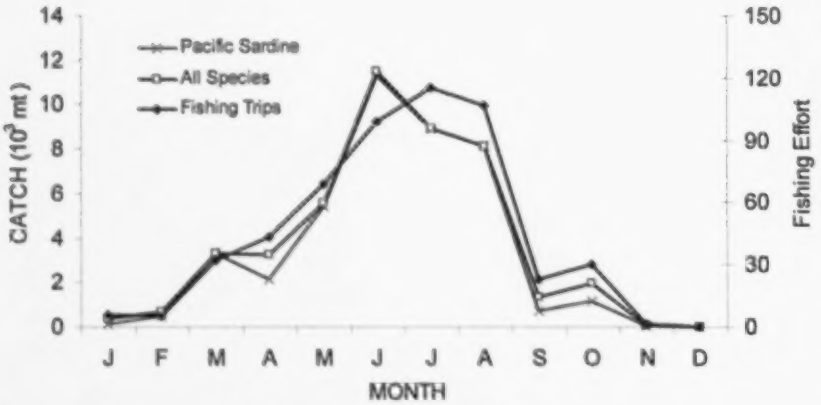

Pacific Sardine
All Species
Fishing Trips
CATCH (10^3 mt)
Fishing Effort
MONTH
J F M A M J J A S O N D
0 2 4 6 8 10 12 14
0 30 60 90 120 150

Figure 1. Monthly catch and effort in Bahia Magdalena in 2009.

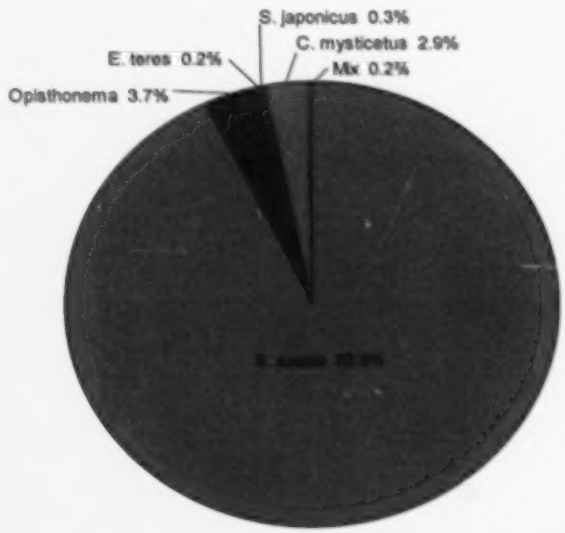


Figure 2. Catch composition of the small pelagic fishes in Bahia Magdalena in 2009.

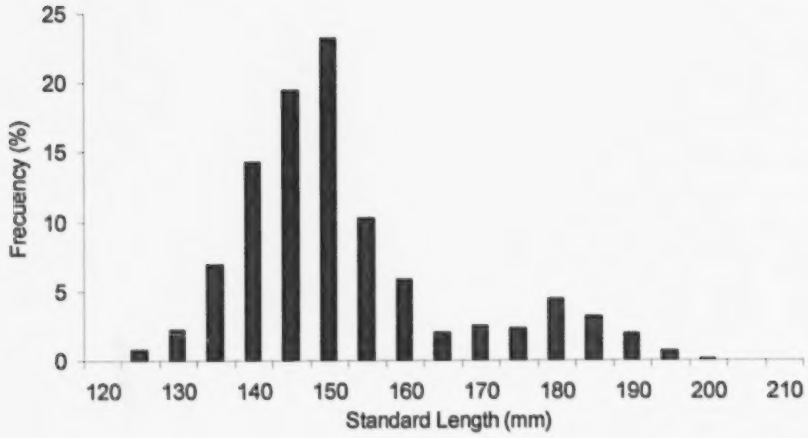


Figure 3. Size structure of the Pacific sardine in Bahia Magdalena in 2009.

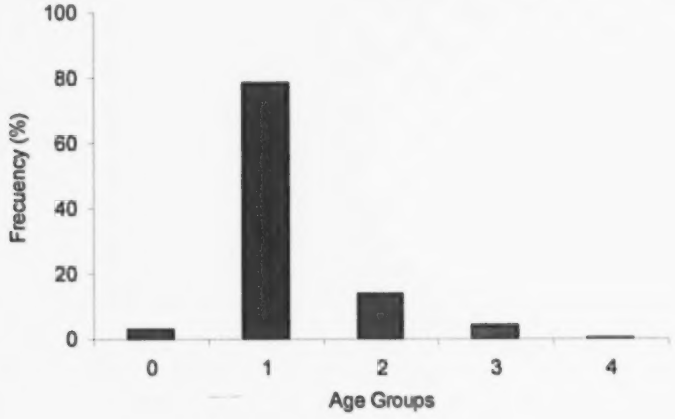


Figure 4. Age structure of Pacific sardine in Bahia Magdalena in 2009.

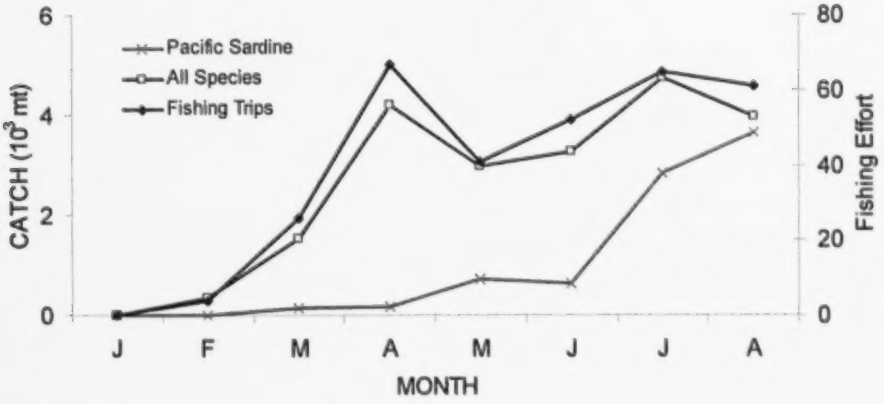


Figure 5. Monthly catch and effort in Bahia Magdalena during January to August 2009.

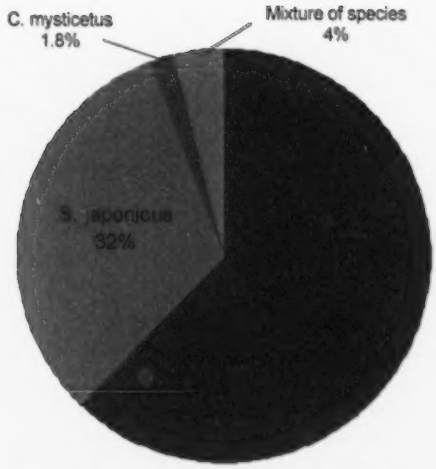


Figure 6. Catch composition of the small pelagic fishes in Bahia Magdalena during 2010.

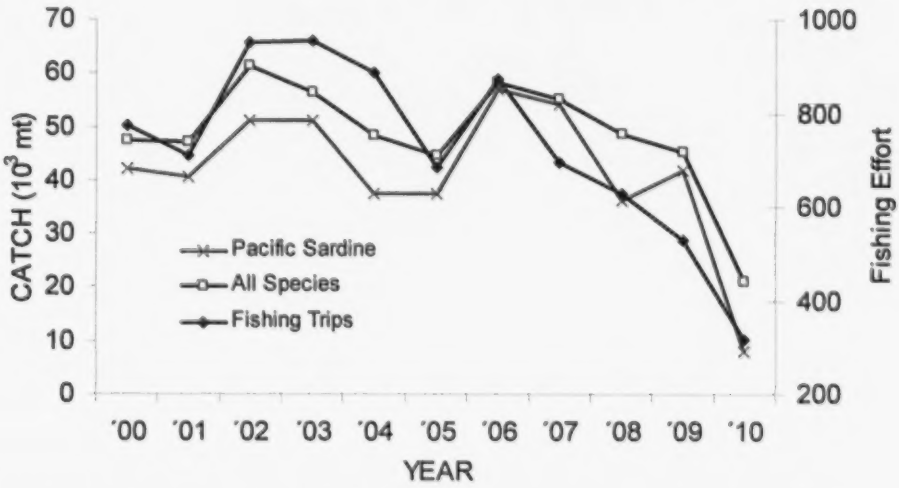


Figure 7. Catch of small pelagic fishes and effort in Bahia Magdalena during 2000-2010.

UNITED STATES

State of Washington, 2010
Lorna Wargo, Washington Department of Fish and Wildlife

The Washington sardine fishery concluded its first full year under a standard limited license program in 2010. Prior to 2009, the fishery was managed with provisional experimental permits which cannot be transferred. Subsequent to the new license program multiple license transfers occurred. Of the 16 permanent licenses, only 8 were actively fished in 2010. Temporary annual permits may be considered if supported by sardine abundance, forage needs and market

demand. In 2010, one temporary permit was issued. The total number of licenses, including permanent and temporary, cannot exceed 25.
The first management period for sardine coast-wide starts January 1. However, the fishery in Washington remains closed until April 1 to protect juvenile salmonids. Typically there is little effort in Washington in June; the majority of landings occur in July and September. In 2010, a total of 12,252 mt of sardines were landed into Washington during the directed fishery. Total catch was distributed over 232 landings with 4%, 75% and 21% landed in June, July and September, respectively. The average landing into Washington was about 46 mt. All landings were made into Westport or Ilwaco with the majority of the catch (98%) occurring in waters adjacent to Washington. A total of 311 sets were made with 280 (90%) of them successful. The average catch per successful set was about 49 mt. An incidental harvest of just over 2 mt of sardine was caught in anchovy-directed fishing in Washington in July and August.

Ex-vessel price per pound in the fishery averaged $0.10 across the season. Vessels fishing out of Ilwaco and Westport sometimes use spotter planes. In general, pilots receive about 10-15% of the landing revenue. Total ex-vessel value for the fishery was $2.6 million. This compares to an ex-vessel value of $1.6 million in 2009.

	2010	2009	2008	2007	2006	2005	2004
Landings (mt)	12,378	8,009	6,432	4,663	4,362	6,714	8,911
# Landings	232	173	150	106	108	207	236
# Vessels	8	8	5	6	7	11	14

WDFW staff coordinated the collection of biological samples with Oregon Department of Fish and Wildlife (ODFW) staff to ensure sample coverage was evenly distributed throughout the Northwest fishery. Each state (Washington, Oregon, and California) is asked to collect a minimum of one sample of twenty-five sardines per 1,000 mt landed.

Age data for 2010 are not yet available. Sardine ages in the Washington fishery have ranged from one to 10 years; the dominant age class has ranged from two to five years.
In 2009, ages ranged from two to eight years with age-5 fish dominant at 34% percent. Age-4 and age-6 sardines were also numerous at 24% and 26% respectively. In 2009 the dominate age was age-5 sardines at 43%.

Sex and maturity were determined by using the California Department of Fish and Game (CDFG) Standard Maturity Guide for Wetfish, which is based on Hjort, J. (1914):

Code	Description
(1)	Virgin individuals.
(2)	Maturing virgins or recovering spent. Males intermediate; no milt present.
(3)	Yoked oocytes visible. Milt is present and oozing in males.
(4)	Hydrated oocytes present.

Most of the samples analyzed in 2010 were females (58%), with the highest subcategory overall being females with a sexual maturity of two. Most sardines sampled had a maturity level of one or two (95%). A few sardines with a maturity level of three were found in Washington's landings this year (5%). A maturity level of four has never been found in the Washington sardine fishery.

State of California, 2010

Dale Sweetnam, Briana Brady, and Mandy Lewis, California Department of Fish and Game

The Pacific sardine, *Sardinops sagax*, has been a major component of California's commercial fisheries. The historic sardine fishery existed from the early 1900's, crashed in the 1940s, and saw resurgence in the late 1980s. The 2010 California Coastal Pelagic Species limited entry fleet consists of 65 permits on 58 vessels; 35 of those permitted vessels landed sardine.

Through October 2010, sardine is currently California's second largest fishery by volume and fifth in ex-vessel value. Statewide landings as of November 7, 2010 were 65,495,000 pounds (29,708 metric tons) with an ex-vessel value of over $3.9 million. This represents a 24% decline in volume, and a 30 percent drop in revenue over 2009 in which sardine was California's second largest fishery by volume, 82.8 million pounds (37,543 metric tons), and sixth in ex-vessel value at $5.6 million. This also represents a 48 percent decrease in volume from 2008, in which landings were estimated at 127.4 million pounds (57,803 metric tons) with an ex-vessel value of approximately $7.6 million. The average price for sardine was $0.06 per pound, a slight drop from the $0.07 per pound in 2009. Landings occurred mainly in the San Pedro-Terminal Island and Monterey-Moss Landing port complexes.

In 2010, the coast-wide harvest guideline (HG), as adopted by the Pacific Fishery Management Council (PFMC), was completely taken. This is the third time since its resurgence that the sardine HG had been achieved. In November 2009, the Council adopted a total HG of 72,039 metric tons for the 2010 Pacific sardine fishery, which extends from California to Washington. A research set aside of 5,000 tons used for an Experimental Fishing Permit (EFP) to do coast-wide aerial surveys and evaluate survey methodologies (photographic, acoustic, and LIDAR) in the fall dropped the HG to 67,039. This HG was allocated in three parts based on an annual (Jan 1 – Dec 31) management cycle. The 1st allocation (Jan 1 – June 30) lasted 162 days. This was markedly longer than the 2nd (July 1 – Sept 14) and 3rd (Sept 15 – Dec 31) allocations which lasted 21 and 9 days, respectively. Increased fishing efforts, such as vessels making multiple landings per day, were observed during all allocation periods. Fishing effort continued during weekends, a period normally not fished. The 2009 fishery behavior was characteristic of a "derby" style fishery, leading to a temporally shortened directed fishery. The directed Pacific sardine fishery was officially closed by NOAA Fisheries on September 24, 2010.

Fishery dependent sampling in 2010 indicate that the average length of sardines from Monterey and San Pedro were not significantly different in 2010. In addition, sardines in both areas were significantly smaller than the same areas from 2009. The majority of landings came from southern California (87%) in 2010. This is dramatically different from 2009 in which 64% of the landings came from Monterey and Moss Landing. On November 7, 2010, the Council adopted a HG of 50,026 metric tons for the 2011 Pacific sardine fishery based on a biomass estimate of 537,173 metric tons and the harvest control rule in the Coastal Pelagic Species Fishery Management Plan. This HG also incorporates a 4,200 metric ton set-aside allocated for dedicated Pacific sardine research consisting of an aerial survey in Oregon and Washington, and a highbred survey in California depending on survey results this fall.

CANADA

Province of British Columbia, 2010
Cynthia Johnston, Department of Fisheries & Oceans Canada

The Canadian Pacific Sardine fishery is an opportunistic fishery that depends on the migration of sardines into Canadian waters. The 2010 fishery runs from June 1 to February 9. The first landing of the 2010 season occurred on June 21.

The Total Allowable Catch (TAC) was set at 23,166 MT. The TAC was calculated by applying the 2010 migration estimate of sardine into BC waters (22%) and a fixed harvest rate (15%) to the 2010 US stock assessment figures (702,024 MT). The TAC was equally divided amongst two licence categories, commercial and communal commercial, with each licence receiving an equal quota of 463.3 MT. All 50 available licences were issued for the season.

Since 2007, harvesters have been permitted to designate multiple licences to a single vessel which allows for increased in-season flexibility for harvesters and has helped to increase the amount of the total allowable catch landed since it was implemented. eg. 12% of the TAC was harvested in 2007 compared to 84% in 2008. Table 1 shows the catch history from 2002 to 2010.

There were 13 active vessels that participated in the fleet in 2010. As of October 31, 2010, the majority of the catch occurred on the west coast of Vancouver Island. In total, 18,439 MT of Pacific sardine has been harvested to October 31, 2010. In addition to sardine, fishers are also permitted to harvest 10 MT of chub and jack mackerel, which must be recorded in the logbook and validated at dockside. This is to decrease wastage of mackerel that is normally encountered when fishing for Pacific sardines – and is not to create a directed fishery. All other bycatch must be released.

Catch in the fishery is monitored through a third party service provider that is funded by industry. The monitoring program has several requirements, including hailing in and out to the fishery, submission of logbooks with catch & effort information, 100% dockside validation of catch and at-sea observers. At-sea observer coverage varies depending on the fishing location and month. 25% observer coverage is in effect throughout the season for areas of no concern, while 100% observer coverage is required in areas of concern for wild Chinook populations.

The Department of Fisheries and Oceans has established priorities for the management of Canadian fisheries. The Department is working to ensure the monitoring program meets Canada's catch monitoring standards while being cost effective for harvesters, to improve cooperation and compliance with conditions of licence, and to continue developing shared stewardship arrangements for cost sharing of science and management activities. A new program was piloted for 2010 with reduced observer coverage in areas of no concern for incidental salmon catch. The program is being reviewed to ensure the quality of the data and compliance with reporting obligations.

Table 1. Annual summary of catch and effort in Canadian waters from 2002 to 2010.

YEAR	Individual Licence Quota (MT)	% of TAC	CATCH (MT)	TAC (MT)
2002	180	9%	822	9,000
2003	180	11%	1,006	9,000
2004	300	28%	4,259	15,000
2005	304	21%	3,266	15,200
2006	270	15%	1,558	13,500
2007	396	12%	1,524	19,800
2008	250	84%	10,435	12,491
2009	364	84%	15,334	18,196
2010*	463	80%	18,439	23,166

2010 Data is preliminary (to October, 2010)

REGIONAL BIOMASS REPORTS

UNITED STATES

Objectives :To estimate spawning biomass of Pacific sardine from Baja California, Mexico to Vancouver Island, British Columbia, Canada.

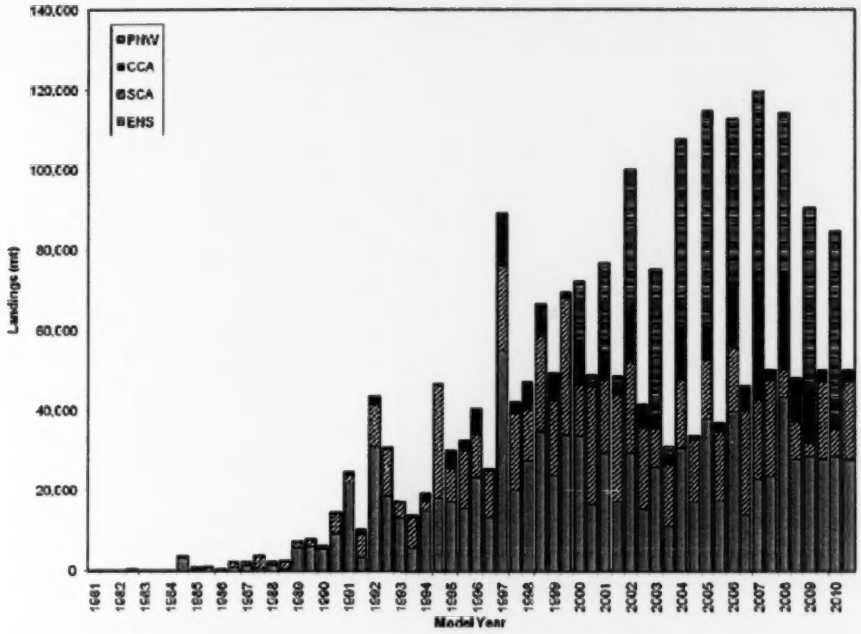
Coastwide Assessment

Kevin T. Hill, Nancy C. H. Lo, Beverly J. Macewicz, Paul R. Crone, and Roberto Felix-Uraga

Stock: The Pacific sardine (*Sardinops sagax caerulea*) ranges from southeastern Alaska to the Gulf of California, México, and is thought to comprise three subpopulations. In this assessment, we model the northern subpopulation which ranges seasonally from northern Baja California, México, to British Columbia, Canada, and offshore as far as 300 nm. All U.S., Canada, and Ensenada (México) landings are assumed to be taken from a single northern stock (Table 1). Future modeling efforts will explore a scenario separating the catches in Ensenada and San Pedro into the respective northern and southern stocks based on objective criteria.

Catches: The assessment includes sardine landings from four commercial fisheries: Ensenada (México), Southern California (San Pedro to Santa Barbara), Central California (Monterey Bay region), and the Pacific Northwest (Oregon, Washington, and British Columbia), from 1981 to 2010.

Model Year	ENS	SCA	CCA	PNW
2001	46,948	44,939	8,042	25,683
2002	44,938	43,125	17,589	36,123
2003	37,040	25,141	4,508	39,861
2004	48,007	32,581	13,278	47,747
2005	55,600	31,991	9,857	54,254
2006	53,617	42,472	21,724	41,221
2007	46,353	43,982	31,284	48,237
2008	71,236	16,214	35,275	39,800
2009	56,357	22,730	16,841	44,841
2010	56,357	26,291	4,842	47,502



Data and assessment: This assessment update was conducted using 'Stock Synthesis' version 3.03a and utilizes fishery and survey data collected from mid-1981 through mid-2010. The model uses a July-June 'model year', with two semester-based seasons per year (S1=Jul-Dec and S2=Jan-Jun). Fishery data include catch and biological samples for the fisheries off Ensenada, Southern California, Central California, and the Pacific Northwest. Two indices of relative abundance are included in the base model: Daily Egg Production Method and Total Egg Production estimates of spawning stock biomass (1986-2010), both based on annual surveys conducted off California. Finally, the 'tuned' update model '10w' was run with the addition of aerial (northern region) survey estimates of absolute abundance from 2009 and 2010 (q=1) to derive population quantities for 2011 management.

Stock biomass and recruitment: Stock biomass, used for determining the HG, is defined as the sum of the biomass for sardines ages 1 and older. Biomass increased rapidly through the 1980s and 1990s, peaking at 1.57 mmt in 2000. Biomass has subsequently trended downward to the present (July 1, 2010) level of 537,173 mt.

Recruitment was modeled using the Ricker stock-recruitment relationship. The estimate of steepness was high (h=2.253). Virgin recruitment (R0) was estimated at 4.62 billion age-0 fish for the base model. Recruitment increased rapidly through the mid-1990s, peaking at 17.156 billion fish in 1997, 19.743 billion in 1998, and 18.578 billion in 2003. Recruitments have been notably lower from 2006 to 2009.

Model Year	Stock biomass (ages 1+, mt)	Recruits (age-0, billions)
2000	1,570,120	2.928
2001	1,382,790	7.959
2002	1,211,880	0.804
2003	938,187	18.578
2004	1,049,690	9.617
2005	1,166,640	10.448
2006	1,248,410	3.277
2007	1,137,980	3.596
2008	919,328	2.674
2009	683,575	4.613
2010	537,173	---

Exploitation status: Exploitation rate is defined as calendar year catch divided by total mid-year biomass (July-1, ages 0+). Exploitation rate was relatively high during the early recovery period (mid-1980s) but declined and stabilized as the stock underwent the most rapid phase of recovery. Exploitation rate has subsequently increased in recent years as the stock has decreased in size. Based on the update model '10w', total coast-wide exploitation rate is currently ≈23%.

Calendar Year	ENS	SCA	CCA	PNW	Total
2000	4.3%	2.9%	0.7%	1.0%	8.9%
2001	3.2%	3.3%	0.5%	1.7%	8.7%
2002	3.8%	4.0%	1.2%	3.2%	12.2%
2003	3.7%	2.7%	0.7%	3.4%	10.6%
2004	3.7%	2.9%	1.3%	4.3%	12.2%
2005	4.4%	2.4%	0.6%	4.4%	11.8%
2006	4.5%	2.6%	1.4%	3.2%	11.7%
2007	3.1%	3.9%	3.0%	4.1%	14.2%
2008	7.1%	3.3%	2.8%	4.2%	17.4%
2009	7.8%	1.7%	3.5%	6.2%	19.2%
2010	9.4%	4.4%	0.8%	7.9%	22.5%

Management performance: Based on results from the update model '10w', the harvest guideline for the U.S. fishery in calendar year 2011 would be 50,526 mt. The HG is based on the control rule defined in the CPSFMP:

HG2011 = (BIOMASS2010 – CUTOFF) • FRACTION • DISTRIBUTION;

where HG2011 is the total U.S. (California, Oregon, and Washington) harvest guideline in 2011, BIOMASS2010 is the estimated July 1, 2010 stock biomass (ages 1+) from the assessment (537,173 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries (see below), and DISTRIBUTION (0.87) is the average portion of BIOMASS assumed in U.S. waters. The following formula is used to determine the appropriate FRACTION value:

FRACTION or $Fmsy = 0.248649805(T2) - 8.190043975(T) + 67.4558326$;

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding seasons (July-June). Based on the current ($T2010$) SST estimate of 17.90 °C, the *Fmsy* exploitation fraction should remain at 0.15. The new U.S. HG (50,526 mt) would be the lowest since management was initiated under the federal CPS-FMP:

Year	U.S. OFL	U.S. HG	U.S. Landings	Total OFL	Total Landings
2000	273,907	186,791	72,496	314,835	142,063
2001	204,816	134,737	78,520	235,421	125,857
2002	149,585	118,442	101,367	171,937	148,951
2003	165,826	110,908	74,599	190,604	116,918
2004	188,902	122,747	92,613	217,129	138,948
2005	206,730	136,179	90,130	237,621	148,684
2006	183,845	118,937	90,776	211,316	149,588
2007	228,478	152,564	127,695	262,618	166,065
2008	144,234	89,093	87,175	165,786	164,466
2009	114,820	66,932	67,084	131,976	138,775
2010	121,598	72,039	63,066	139,768	---

Coast-wide survey, CalCOFI, and IMECOCAL 2010

California DEPM and Calcofi, MARCH-APRIL CRUISES, 2010: The spring 2010 California Current Ecosystem (CCE) survey was conducted aboard one NOAA research vessel and a chartered fishing vessel. The NOAA ship *Miller Freeman* (April 2 – 22) covered the area off California from San Diego to Monterey Bay (CalCOFI lines 95 to 66.7) and the F/V *Frosti* (March 28 – April 28) covered the area from just south of Cape Flattery, Washington to just south of Monterey Bay, California (48.07°N to 34.88°N, i.e. CalCOFI line 70). During the CCE surveys, CalVET tows, Bongo tows, CUFES and trawls were conducted aboard both vessels. After the CCE survey, the routine spring CalCOFI survey was carried out aboard the NOAA ship *Miller Freeman* from April 26 – May 17 to cover six lines from 93.3 to 76.6 and only CalVET and Bongo tows were taken. Only data from CCE survey were included in estimation of spawning biomass of Pacific sardines.

In addition to sardine eggs and yolk-sac larvae collected with the CalVET net, yolk-sac larvae collected with the Bongo net have been included to model the sardine embryonic mortality curve since 2000. Beginning in 2001 (Lo et al. 2001), CUFES data from the ichthyoplankton surveys have been used only to map the spatial distribution of the sardine spawning population with the survey area post-stratified into high-density (Region 1) and low-density (Region 2) areas according to the sardine egg density from CUFES collections. Staged eggs from CalVET tows and yolk-sac larvae from CalVET and Bongo tows in the high-density area have been used to model embryonic mortality in the high density area and later converted to the daily egg production, P_0, for the whole survey area.

For adult samples, the survey plan was to use the *Miller Freeman* and the *Frosti* to conduct 3 – 5 trawls a night either near regular CalCOFI stations or at random sites on the survey line regardless of the presence of sardine eggs in CUFES collections. In addition, it was planned to conduct some directed trawls in the daytime on acoustic targets to verify potential sardine schools. At night a Nordic 264 rope trawl with 3.0 m^2 foam core doors was towed for 30 minutes at the surface (0 – 11 meters). The trawl was modified for surface trawling with Polyform floats

attached to the head rope and trawl wings. The trawl was modified with a marine mammal extruder device placed midsection just forward of the codend. In the daytime, the trawl was used without the Polyform floats and towed at depths of 14 to 174 meters. For the whole CCE survey trawling occurred from March 30 to April 27, 2010 and 19 of the 90 trawls conducted at night were positive for Pacific sardines but none of the 8 trawls conducted during daylight hours contained sardines. The trawls with sardines were located in the south below latitude 38.2°N (Figure 1).

Since 2009, in addition to the estimates of spawning biomass based on the past procedure by which, the P_0 was a weighted average with weights being the area size (km^2) of each region, whereas the adult parameters were estimated from all trawl samples in the entire survey area, an alternative estimator based on the stratified sampling for each parameter had been also included (Hill et al. 2010) for years when adequate adult samples were available, e.g. 1986,1987,1994,2004,2005,2007-2010. The original time series of spawning biomass may not comparable due to slightly different estimation procedures and the refined survey designs over time. This alternative method was also used to estimate the female spawning biomass, an input time series for the stock assessment. The time series of spawning biomass based on the original method and the stratified estimates were report in Lo et al (2010).

The spawning biomass of the Pacific sardine (*Sardinops sagax*) in April 2010 was estimated using the daily egg production method (DEPM) calculated by two methods: 1) the traditional method where the egg production (P_0) was a weighted mean while each adult parameter was an unstratified estimate, and 2) a stratified procedure where the estimate of total spawning biomass is the sum of the estimated spawning biomass in each of two regions representing high and low spawning activity. Thus the two estimates of the spawning biomass were 100,578 mt (CV = 0.38) and 96,622 mt (CV = 0.38) for the entire survey area of 477,092 km^2 off the west coast of North America from San Diego, U.S.A. to Cape Flattery, Washington (30.6° – 48.07°N), primarily for the area south of 38°N. The daily egg production estimate (P_0, a weighted average with area as the weight) was 0.21/.05m^2 (CV = 0.32). No eggs were collected in the area north of CalCOFI line 56.7, and sardines were caught at only one station north of CalCOFI line 60 (at 38.2°N). The standard DEPM survey area off California, from San Diego to San Francisco (CalCOFI lines 95 to 60), in 2010 was 271,773 km^2 and the egg production estimate was 0.36/0.05m^2 (CV = 0.40). The two estimates of spawning biomass of the Pacific sardine (*Sardinops sagax*) in April 2010 for the standard DEPM area were 108,280 mt (CV = 0.46) and 105,220 mt (CV = 0.40). The point estimates of total spawning biomass for the standard DEPM survey area were greater than those for the whole survey area using either the traditional method or the stratified procedure. However, the differences of spawning biomass between the standard DEPM survey area and the entire survey area were not statistically significant due to the high CV values. In the standard DEPM area, the estimates of female spawning biomass calculated by the two methods were 62,131 mt (CV = 0.46) and 58,447 mt (CV = 0.42).

The estimated of daily specific fecundity was 18.07 (number of eggs/population weight (g)/day) using the following estimates of reproductive parameters from 313 mature female Pacific sardines collected from 17 positive trawls: F, mean batch fecundity, 39304 eggs/batch (CV = 0.03); S, fraction spawning per day, 0.104 females spawning per day (CV = 0.22); W_f, mean female fish weight, 129.5 g (CV = 0.02); and R, sex ratio of females by weight, 0.574 (CV = 0.07). Since 2005, trawling has been conducted randomly or at CalCOFI stations, which resulted in sampling adult sardines in both high (Region 1) and low (Region 2) sardine egg-density areas. In 2010, more positive tows were observed in Region 2 than Region 1.

The estimates of spawning biomass of the Pacific sardine off California in 1994 – 2010 based

on the traditional method are: 127,000 mt, 80,000 mt, 83,000 mt, 410,000 mt, 314,000 mt, 282,000 mt, 1.06 million mt, 791,000 mt, 206,000 mt, 485,000 mt, 300,000 mt, 600,000 mt, 837,000 mt, 392,00 mt, 117,000 mt, 185,000 and 108,000mt (for the standard DEPM area), respectively. These estimates of spawning biomass indicate that there has been considerable fluctuation during this time (the peaks occurred in 2000 and 2006) and that biomass has declined in the recent years.

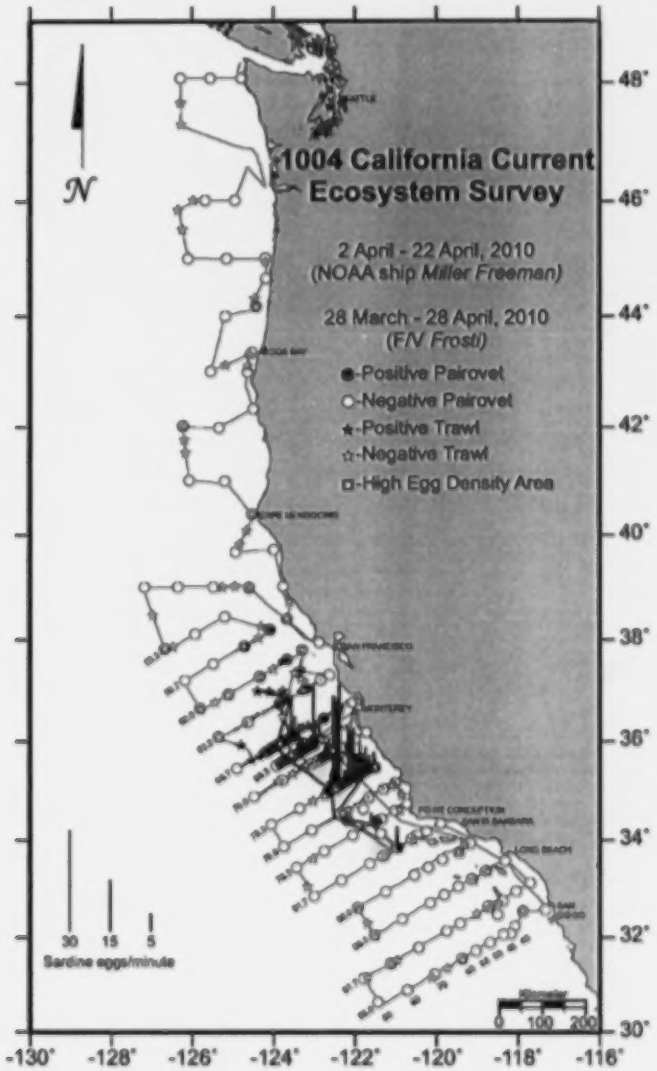


Figure 1. Location of sardine eggs collected from CalVET a.k.a. Pairovet (circle) and from CUFES (sticks) and trawl location (star) during the 2010 survey. Region 1 is high density area. Dates of cruises refer to the first and last tow. Solid and open symbols are positive and zero catches. The standard DEPM survey area is south of San Francisco.

IMECOCAL in 2010: The IMECOCAL monitoring program of quarterly cruises was initiated in October, 1997 with *in situ* sampling from the 28 m CICESE research vessel *Francisco de Ulloa*. The tracklines and station locations are based on the sampling grid of the original CalCOFI plan off Baja California with core measurements of hydrography and biological sampling that follow similar protocols. To the extent possible, the IMECOCAL cruises are scheduled to coincide with the CalCOFI cruises. One of the Bongo net samples is sent to CICIMAR in La Paz for analysis and counting of icthyoplankton while the other sample is analyzed at CICESE for displacement volumes and identification and counting of major taxonomic groups of zooplankton collected from each cruise. Continuous sampling of small pelagic fish eggs onboard the *R/V Ulloa* was initiated in January, 2000, after installation, testing and modification of the CUFES system in summer and fall of 1999. Because sardine spawning occurs throughout the year off Baja California the CUFES system is operated on all the quarterly cruises. The relatively small size of the *R/V Ulloa* subjects it to strong movement in a seaway and also limits the number in the scientific party, so the CUFES samples are fixed and stored until they can be counted later onshore.

CUFES Surveys and Egg Counts Completed during 2010: Three cruises were conducted during 2010 over the IMECOCAL sampling grid. The winter cruise planned for January was cancelled due to unscheduled, emergency ship repairs needed for the *R/V Ulloa*. CUFES and Bongo samples were taken on the three cruises during spring, summer and fall. The egg counts of the 2009 April cruise were also postponed in favor of work on the April 2010 samples to provide more recent information to support a request for a permit for offshore exploratory trawling for sardines that is now under review. The egg counts of the CUFES samples from the April 2010 cruise were completed at the CICESE lab at the end of 2010 although the sample positions have not been scanned for quality control and are not yet integrated into a single data file.

It is important to mention here that there are generally significant delays in producing the final data sets for the IMECOCAL CUFES surveys. These delays result from a lack of permanent technical support staff at CICESE that affect not only the counting of the egg samples, but also the processing and integration of the underway navigation and the continuous temperature and salinity data from the onboard thermosalinometer. For the last five years a single temporary half-time technician has been the only available person for counting the egg samples in the CUFES lab while the processing and quality control of navigation and thermosalinometer data have been done by various short-term contract workers. In the past several years rust particles in the through-hull pumping system have also slowed down the counting so that a second half-time apprentice technician has been hired to separate the eggs and to remove rust and associated debris from the samples. Since both of the technicians are also needed at sea, the cleaning and counting of samples in the shore lab must be interrupted for the cruise preparations and sampling on the quarterly cruises. Needless to say these delays have created a significant backlog of unprocessed samples since the beginning of the CUFES surveys in 2000. Assistance with counting from SIO and SWFSC in La Jolla has eased this backlog, at least for the April samples, although we still do not have a complete series of April egg survey data completed from 2000 through 2010. The full set of quarterly cruises for 2000 and 2001 were completed in reasonable time during the early period of IMECOCAL with several grants providing for one full time experienced technician and a half-time apprentice to count the egg samples. During 2010 we have arranged with CICIMAR for assistance in counting the samples for January, July and October cruises for 2005, which is now underway with July and October cruises finished and January underway.

Current State of the Analyses of the April CUFES Sample Sequence: The current state of the analyses of the April CUFES sample sequence from the IMECOCAL cruises is summarized in

Table 1 using the raw counts of total egg numbers for sardines and other small pelagic species from 2000 through 2010. Counting of the April 2000 samples was done at CICESE for sardine and anchovy only; the 2001 samples were analyzed for sardines at the INP Regional Center (CRIP) at Mazatlan. The 2002 samples were analyzed at the Checkley lab at SIO with the addition of jack mackerel to the species included in the counts. The 2003, 2004, 2005, and 2008 sample sets were counted at SWFSC at La Jolla with the addition of hake to the species list plus squid eggs. The 2007 samples have not yet been counted, and work on the counting of the 2009 samples is underway at CICESE and is expected to be completed during second semester of 2011. These values provide a crude annual index of overall egg densities for a preliminary comparison of the relative egg abundances sampled over the IMECOCAL region. The total egg numbers for sardines, anchovies and jack mackerel (*Sardinops sagax, Engraulis mordax, and Trachurus symmetricus*) are plotted in Figure 2. This figure shows that jack mackerel egg numbers are an order of magnitude greater than the sardine and anchovy counts requiring separate vertical scales on the plot. Figure 2 also points to what appears to be an emerging trend of a reduction in sardine eggs numbers over the period of the decade from the significantly higher counts during the first three years. However, this cannot be clearly determined until the 2007 and 2009 counts are completed. The strong peak in the series of IMECOCAL sardine egg numbers occurred in 2001 during a period of anomalously low temperatures during which a clear southward shift was observed in the CalCOFI egg distribution (see the full set of egg distribution maps published in Bjorkstedt et al. 2010, State of the California Current in *CalCOFI Reports*). The very low values of sardine egg counts of April 2003, 2005, and 2010 in Figure 2 are associated with generally strong anomalous warming and are possibly the result of a combination of northward displacement of adults into the CalCOFI region and earlier spawning off Baja California compared to California.

Table 1. Summary of the raw counts of total eggs in samples from the IMECOCAL CUFES surveys conducted on the spring cruises centered on April.

Cruise Dates	Year	Fish Egg Counts for CUFES Surveys of the IMECOCAL April Cruises						
		Sardine	Jack Mackerl	Anchovy	Pacif. Mackral	Hake	Squid Eggs	Othr Fsh Eggs
4-21 Apr	2000	942	nd	922	nd	nd	nd	23616
5-15 Apr	2001	1980	nd	nd	nd	nd	nd	nd
19 Apr-9 May	2002	768	2644	0	nd	nd	nd	10115
4-24 Apr	2003	160	7562	29	nd	3	254	9872
15 Apr-7 May	2004	613	10210	915	nd	9768	121	28576
14 Apr-6 May	2005	10	24	7	nd	2848	57	5758
19 Apr-2 May	2006	380	4315	671	nd	nd	nd	18238
	2007	xxxxxxxxxxxx not yet counted xxxxxxxxxxxx						
16 Apr-1 May	2008	164	3380	230	nd	7	102	2869
	2009	xxxxxxxxxxxx counting underway xxxxxxxxxxxx						
29 Mar-18 Apr	2010	120	3248	105	1456	2	nd	2397

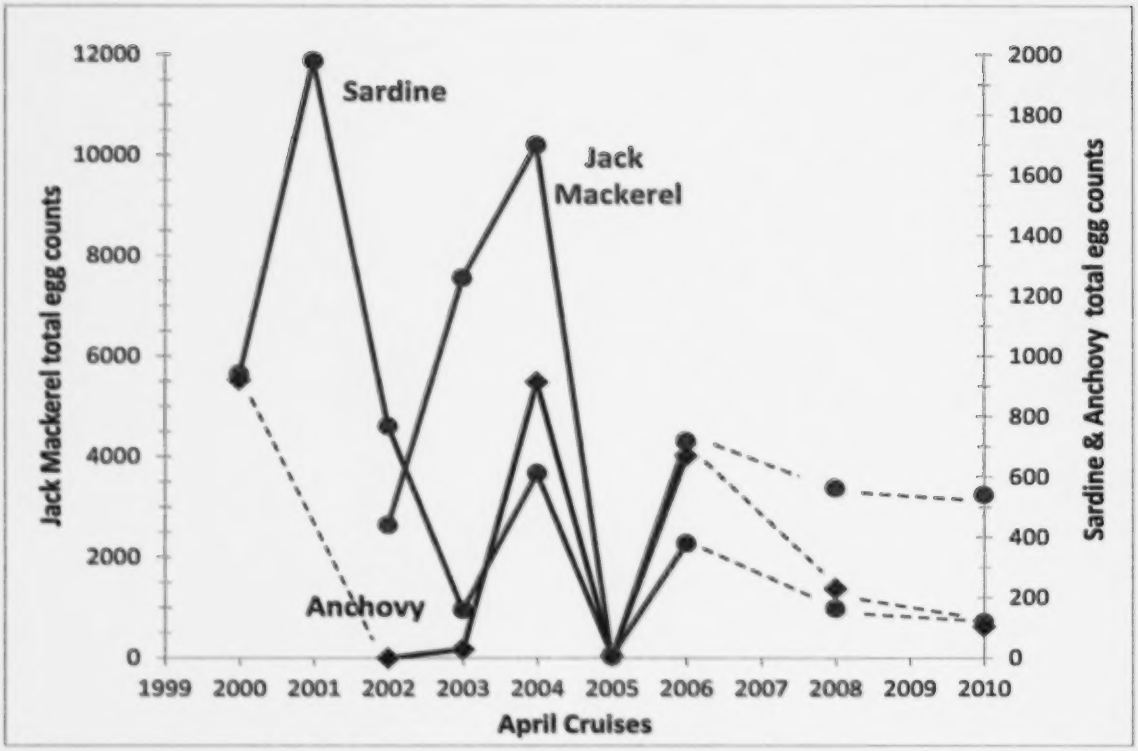


Figure 2. Series of raw counts of total sardine, jack mackerel and anchovy eggs from the CUFES surveys carried out on the IMECOCAL Spring cruises centered on April. Data are presented in Table 1. Note the difference in the vertical scale for jack mackerel versus the scale at right for sardine and anchovy counts.

Figure 3 compares the overall sardine egg distributions during the combined April surveys of CalCOFI and IMECOAL during 2008 (a year with strong anomalously cool ocean temperatures in the NE Pacific and California Current) with those of 2004, a relatively warm year. Dates of the 2004 IMECOCAL cruise on the *R/V Ulloa* were from 15 April through 7 May (Ensenada – Puerto San Carlos in Bahia Magdalena). The 2004 CalCOFI sampling was conducted in two legs aboard the *R/V New Horizon*, (23 March-8 April; San Diego to area off Avila Beach) and the *D.S. Jordan* (13 – 22 April: from SD with diagonal track running to aprox 34◦N, then to San Francisco following CalCOFI grid). Dates of the 2008 IMECOCAL survey by the *R/V Ulloa* were 16 April-1 May (Ensenada to Pto. San Carlos) while the 2008 CalCOFI survey was conducted aboard the *D.S. Jordan* in two legs: 24 March to 9 April (San Diego to San Diego) and from 11 April to 1 May (San Diego to San Francisco). These two periods show markedly different patterns of egg distributions throughout the overall region from the waters off central California down to southern Baja California. The 2004 CalCOFI survey reveals a clear northward shift of the sardine egg distribution, with high egg densities occurring significantly north of Point Conception while the 2008 distribution of sardine eggs was shifted southward with most of the eggs located south of Point Conception. During April 2004 the sardine eggs are located closer to the coast off Baja California than in the Southern California Bight with a pattern of intermittent patches extending down to below Punta Eugenia. The areas of these patches off Baja California are similar to the size and densities of the offshore patches in the CalCOFI region south of 34˚N so that this pattern of reduced egg abundances in the southern CalCOFI region is continued off Baja California, but compressed more towards the coast.

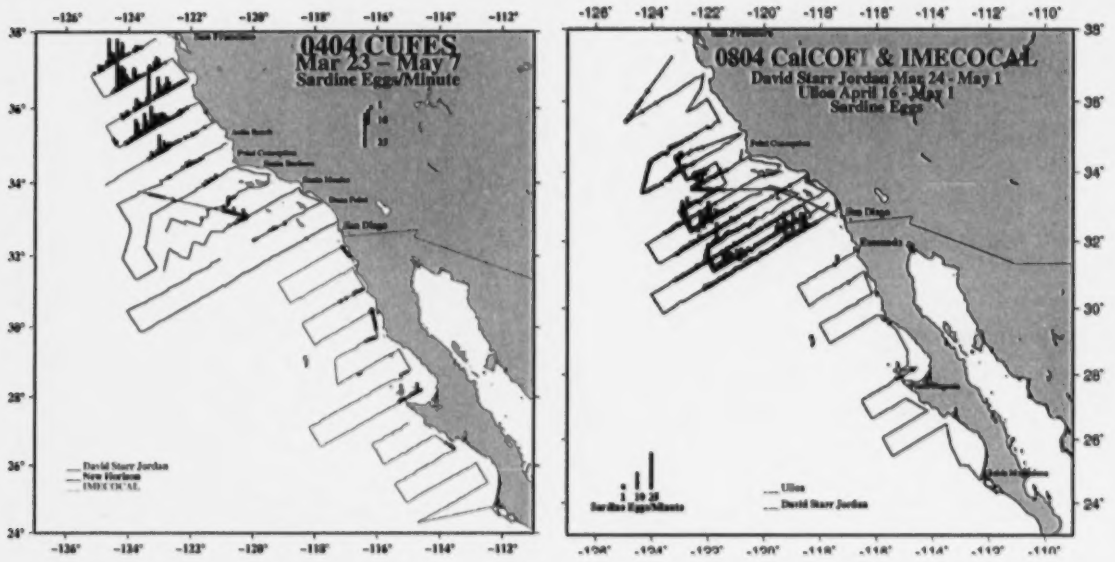


Figure 3. Comparison of the sardine egg distributions from the IMECOCAL and CalCOFI CUFES surveys during Spring of 2004 and 2008.

The 2008 sardine egg distribution also differs from the 2004 pattern for the abrupt decrease in the sardine egg abundances between the CalCOFI and IMECOCAL surveys regions. The near absence of sardine eggs off northern and central Baja California appears unusual given the strong southward shift in spawning in the CalCOFI region. Indeed, the reason for postponing the analysis of the April 2007 samples in favor of counting the 2008 samples was the expectation that the pattern in the sardine eggs observed from the CalCOFI samples would be reflected in a continuation of this southward shift of spawning adults into the region off Baja California with results similar to 2001 that produced the anomalously high sardine egg numbers in Figure 2.

The discontinuity in the pattern of sardine egg distribution between the CalCOFI and IMECOCAL survey regions in Figure 3 appears to indicate that the southward displacement of spawning adults associated with the cool temperatures in April 2008 did not extend into the region off Baja California. If adult sardines were present within the IMECOCAL survey area then they must have nearly finished spawning by the beginning of the cruise in mid April. Another possibility to consider, however, is that southward displacement of the sardine egg distribution in 2008 was accompanied by a significant offshore shift in the western limit of sardine spawning and (unlike the situation in 2001), there may have been a considerable displacement of spawning adults into the region off Baja California, but this may have occurred far enough offshore to fall beyond the reach of the western limit of the IMECOCAL survey and give the appearance that the no significant spawning occurred south of the CalCOFI survey region.

The details of the total egg counts for sardine, jack mackerel and anchovy from the CUFES collections in April 2004 are presented in Table 2 for the individual vessels that covered different areas between San Francisco and Bahia Magdalena. The data are ordered from north to south in the table to show the inverse relationship between sardine and jack mackerel in the north-south distributions with dominance of the sardine in the north and jack mackerel in the south. The significantly higher egg production rates of jack mackerel due to higher spawning frequency and higher batch fecundity of jack mackerel indicate a larger biomass of sardine than jack

mackerel over the total region surveyed during this period in 2004. Anchovy spawning is centered off southern California with a bias towards the south in the distribution of significantly higher egg densities off Baja California than off central California.

Table 2. Total eggs numbers of sardine, jack mackerel (Jack Mackrl) and anchovy from the CUFES samples taken aboard the research vessels *D.S. Jordan* (DSJ) (13-22 April), the *New Horizon* (NH) (23 March-8 April), and the *Fco. de Ulloa* (FdU) (15 April-7 May) during the Spring of 2004. The separate ship tracks are indicated on the plots in Figure 4 along with the egg distributions. The distributions of these egg densities are plotted in Figure 4 along with those of hake.

0404	Sardine	Jack Mackrl	Anchovy
DSJ	11696	1327	39
NH	1043	2848	1534
FdU	613	10201	915

The differences in the latitudinal and offshore distances in the egg distributions of the three species during April 2004 that are given in Table 2 are evident in the individual plots of Figure 4 that also includes a fourth plot with hake egg distribution. A salient feature of the egg distributions in Figure 4 is the high abundance of jack mackerel near the Baja California coast. This is observed also during April 2003 and appears to reflect the displacement of oceanic habitat toward the coast off northern Baja California with compression and reduction of the more coastal-transitional habitat occupied by the sardine in this region. The occurrence of elevated numbers of hake eggs along the coast of Baja California is consistent with such a coastward shift of oceanic habitat.

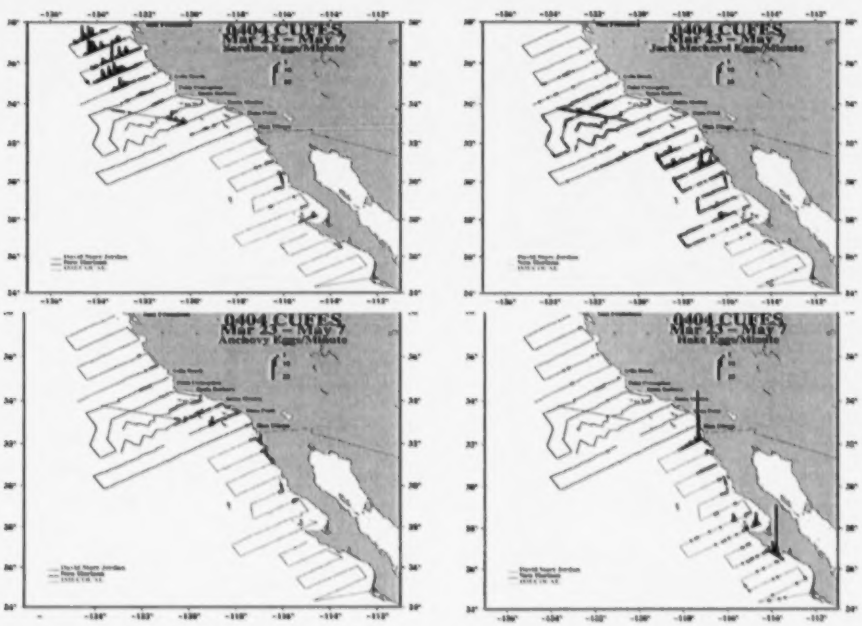


Figure 4. Distribution of egg densities for sardine, jack mackerel, anchovy and hake during April 2004 as sampled by three vessels covering the entire region from north to south (*D.S. Jordan, New Horizon*, and the *Ulloa*).

In the 2009 TSF report, estimates were given for the sardine spawning biomass based on the DEPM for the April 2002 and April 2003 CUFES surveys limited to the northern and central

areas of the IMECOCAL sampling domain. These estimates were 48,000mt for 2002 and 9,200mt for 2003. It should be understood that these are raw estimates that apply only to be the more northerly sardine stock centered off California with peak spawning thought to occur during April. These values appear to underestimate the true spawning biomass off Baja California since the first semester landings by the Ensenada fleet during 2002 were 40% of the DEPM estimate and 170% of the 2003 estimate. Moreover, the narrow operating range of the Ensenada fleet in terms of distance offshore and its limited alongshore range that amount to only a fraction of the area covered by the DEPM from the IMECOCAL CUFES surveys.

Comparison of the historical spawning biomass estimates from the annual series of DEPM estimates in the CalCOFI region with estimates obtained from the Stock Synthesis model (Hill et al., 2009) suggests that the values from the 2002 and 2003 IMECOCAL surveys are strongly biased downwards and should be adjusted for more realistic estimates. A preliminary adjustment of the DEPM values from IMECOCAL surveys based on the relationship between the CalCOFI and the Stock Synthesis results suggests that the DEPM values off Baja California could be up to an order magnitude lower than the actual biomasses[a]. The need for adjustment of the DEPM biomass values suggests that the earlier unrealistic estimates of spawning sardine biomass for years 1997-1999 (2662, 59,000, and 94,000mt) based on sardine larval data from IMECOCAL surveys should be considered to represent the trend in spawning biomass but not as approximations of the true values.

Northern Oregon and Southern Washington, 2010

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Paul Bentley, NOAA Fisheries, Northwest Fisheries Science Center, Hammond, OR
Andrew Claiborne, Pacific States Marine Fisheries Commission, Newport, OR

Objectives: To estimate spawning biomass of Pacific sardine off Oregon since 1994.

Surveys: Three surface trawl surveys and one purse seine survey collected Pacific sardines (*Sardinops sagax*) off Oregon/Washington in 2010. The first two surveys are conducted annually and the third one was started in 2008:

a) The Predator/Forage Fish Survey collected sardines off the Willapa Bay: night surface trawls August 2010 (Figure 5), and
b) The BPA (Bonneville Power Administration) Columbia River Plume Study: collected fish during daytime using surface trawls from northern Washington to Newport, Oregon in May and June 2010 (Figure 6)
c) The lower Columbia River Estuary Purse Seine Study: collected fish during daytime by purse seine at monthly sampling at two locations in the lower Columbia River estuary (Figure 7) from May-July and October 2010.

Abundance estimates and size/age of Pacific sardine: We did not estimate sardine population sizes off the Columbia River in 2010. We were unable to conduct our typical annual survey (surface trawling twice a month at 12 stations, Figure 5) in 2010 because we were unable to contract any fishing vessel to conduct this work.

We did conduct six surface trawls off Willapa Bay (one of our annual survey lines) in August 2010. During this August survey we captured 124 sardines. They ranged in length from 100-250 mm FL. Length/frequency data (Figure 8A) showed two distinct size groups. The smaller

size group (100-150 mm FL) were primarily age-1 and the large size group consisting of age-2 and older, but primarily (29%) age-4 (Figure 8B).

During the Plume Study we also captured primarily two size classes of sardines (Figure 9). However in May 2010 few small <150 mm FL sardines were caught. We captured many more small/young sardines in June 2010.

Sardine length/frequency information from the Estuary Purse Seine Study show that small age-1 sardines (i.e., <150 mm FL) were utilizing the Columbia River estuary (Figure 10), especially in May and June. In October 2010 all sizes/ages were represented.

Oceanographic Conditions in 2010: El Niño conditions were evident off the Pacific Northwest in spring 2010. As a result, ocean sea surface temperatures were anomalously warm in May and mid-June 2010 (Figure 11), with little evidence of upwelling. In May, sardines were wide spread (off La Push, WA to Tillamook, OR) and found in 12°C waters. In June 2010, sardines were found mostly off Grays Harbor, Willapa Bay and Columbia River in 13-14°C waters (Figure 11).

Past surveys have found that during years with anomalous warm ocean conditions sardines would successfully spawn and recruit off the Pacific Northwest. Relatively good sardine spawning and recruitment has been observed when there were anomalous warm June sea surface temperatures in 2003-2005 and 2009 (Figure 12). However, while the ocean in spring 2010 was warm and under El Niño conditions, it quickly moved to cool La Niña conditions by summer and fall. We suspect that this probably reduced the ability of sardine to successfully spawn and recruit off the Pacific Northwest in 2010. Surveys in 2011 will be needed to verify this.

Conclusion: The relatively large number of age-1 sardines captured in 2010 indicates that sardines successfully spawned and recruited off the Pacific Northwest in 2009, probably because of the relatively warm ocean conditions. Because they are small, age-1 sardines do not migrate south during the winter but stay in nearshore Northwest waters, including estuaries during their first year. Unfortunately it is difficult to know how abundant these age-1 sardines were off Oregon and Washington because many appear to have used nearshore areas such as the Columbia River estuary for rearing. We suspect that Willapa Bay and Grays Harbor were also used by age-1 sardines for rearing. Any early spring (April or May) offshore surface trawl sardine surveys would probably have missed these individuals because they appear to stay very nearshore until later in the year.

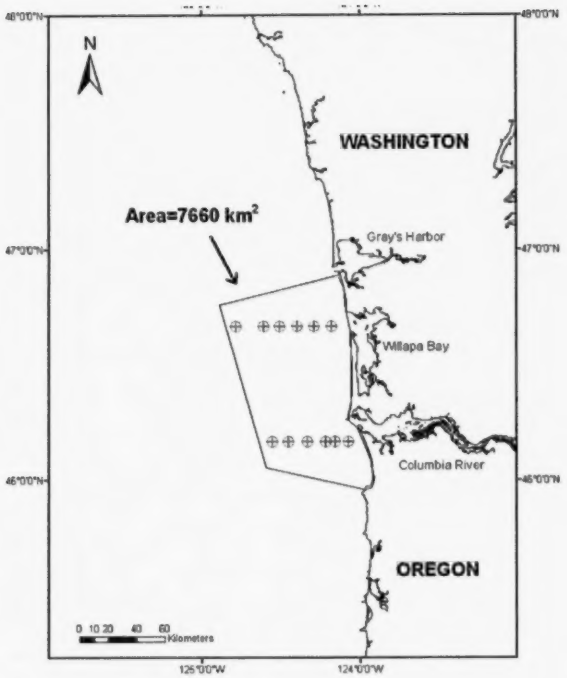


Figure 5. Location of the 12 surface trawl locations that have been sampled from May through August 1998-2010 during the Predator/Forage Fish Surveys. In 2010 only the Willapa Bay line was sampled in August.

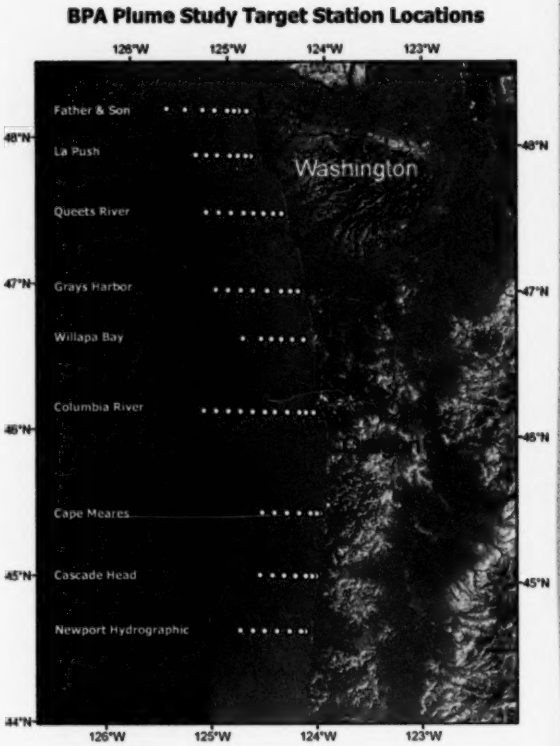


Figure 6. Station location sampled by surface trawl during the day in May and June for the BPA Columbia River Plume Survey.

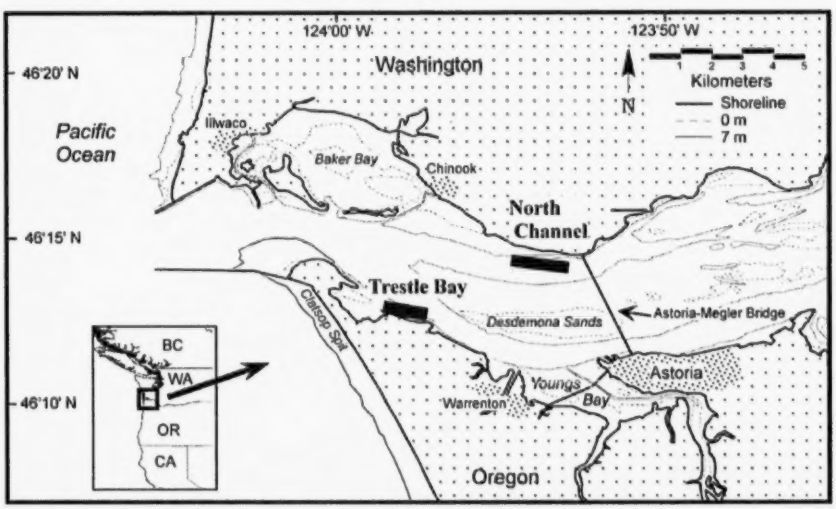
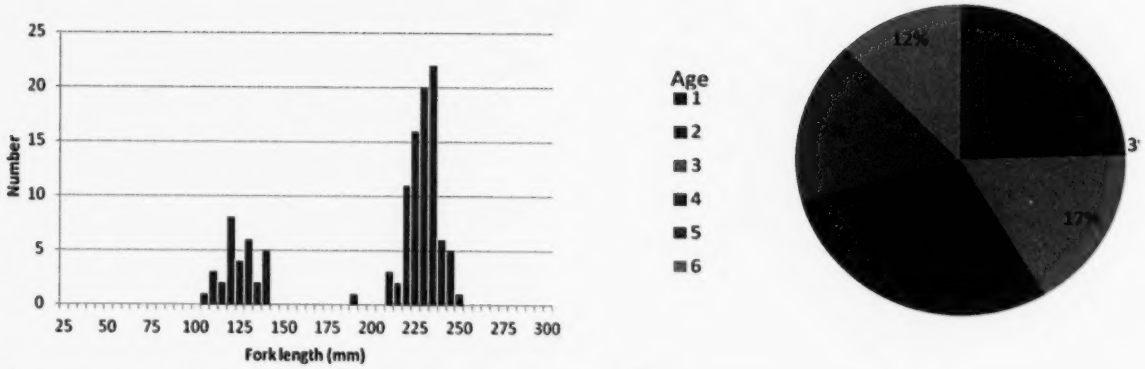


Figure 7. Two locations (black rectangles) where purse seines were used to collect Pacific sardine and other fishes monthly from May-July and September 2010 in the Columbia river estuary.



A. B

Figure 8. A: Length frequency and age of Pacific sardine captured off Willapa Bay, August 2010 and B: age structure of these sardines.

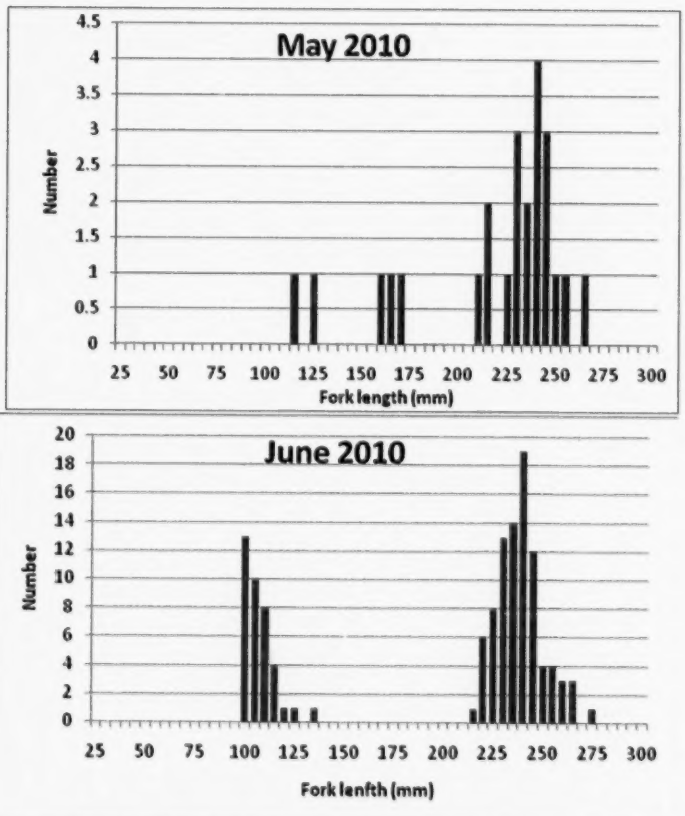


Figure 9. Length frequency of Pacific sardine captured during daytime surface trawling off Oregon and Washington during the BPA Plume 2010 surveys.

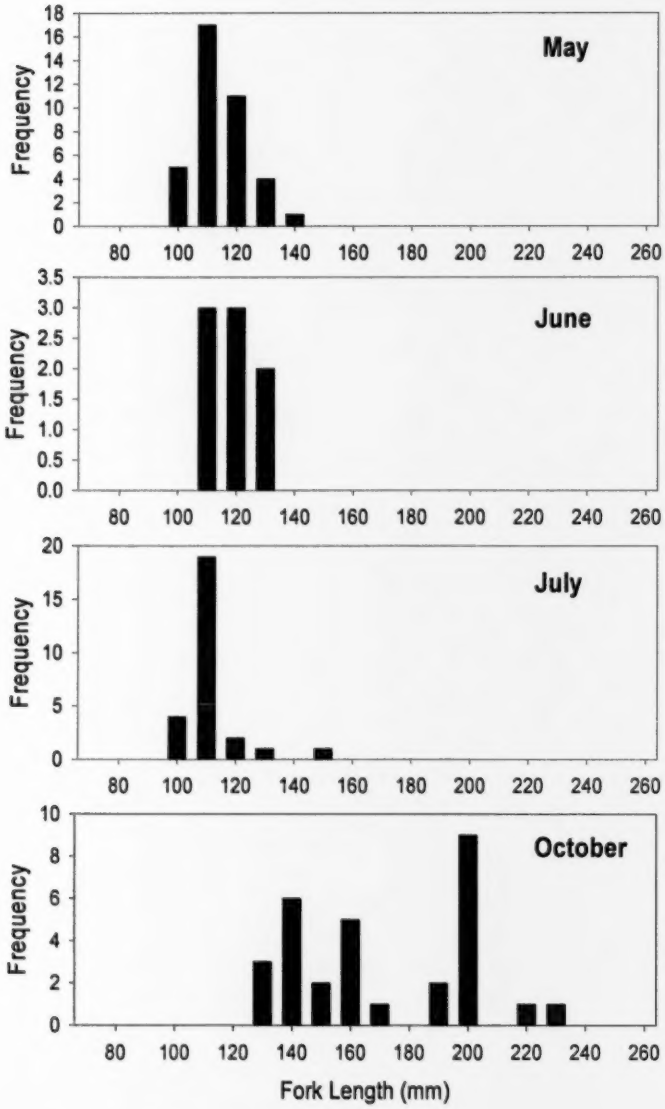


Figure 10. Length frequency of Pacific sardine captured during daytime purse seining in the lower Columbia River estuary in 2010.

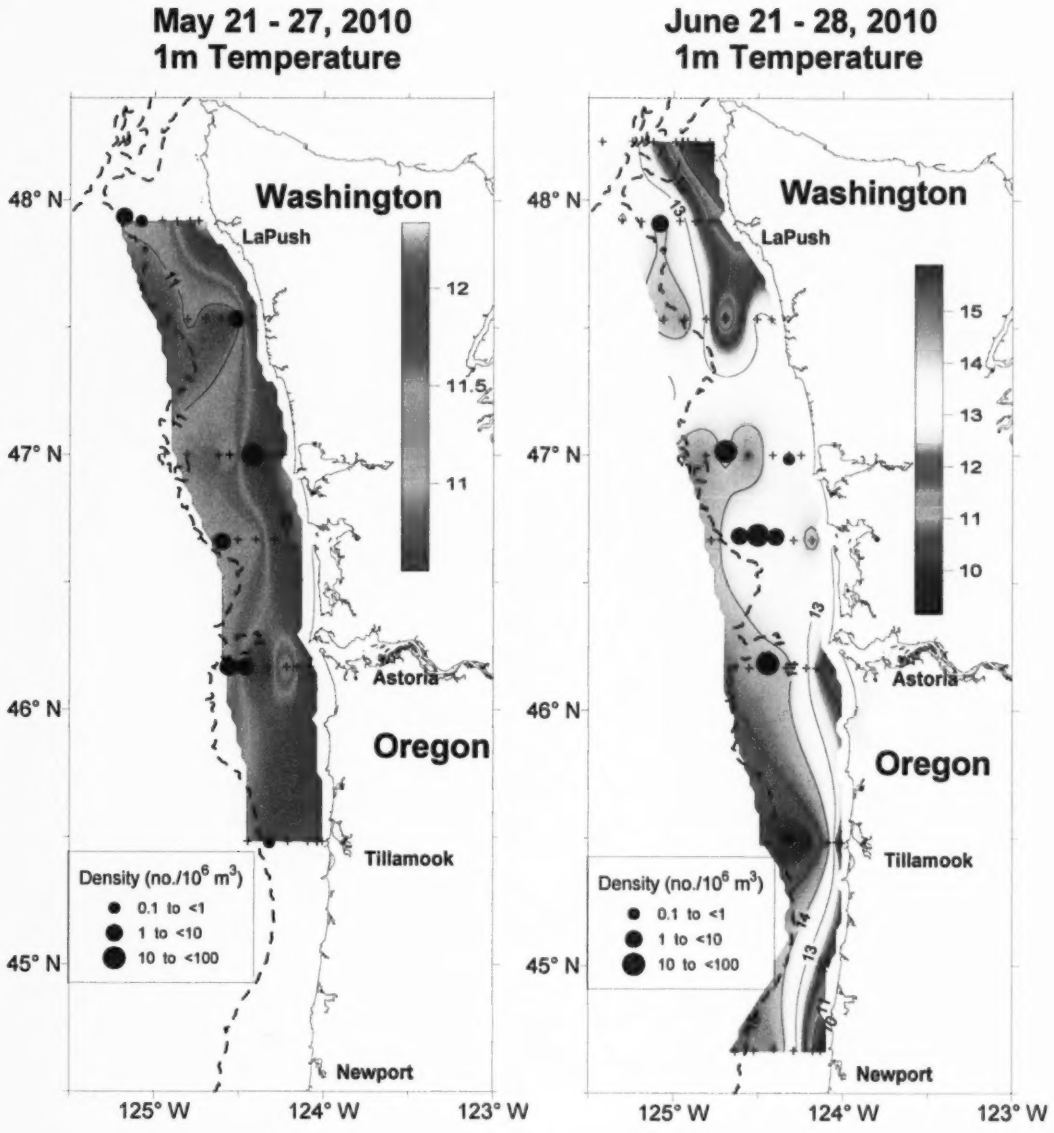


Figure 11. Figure 11. Densities of Pacific sardine captured during daytime surface trawling in May and June 2010 off Oregon/Washington during the annual BPA Plume Survey and associated sea surface temperatures.

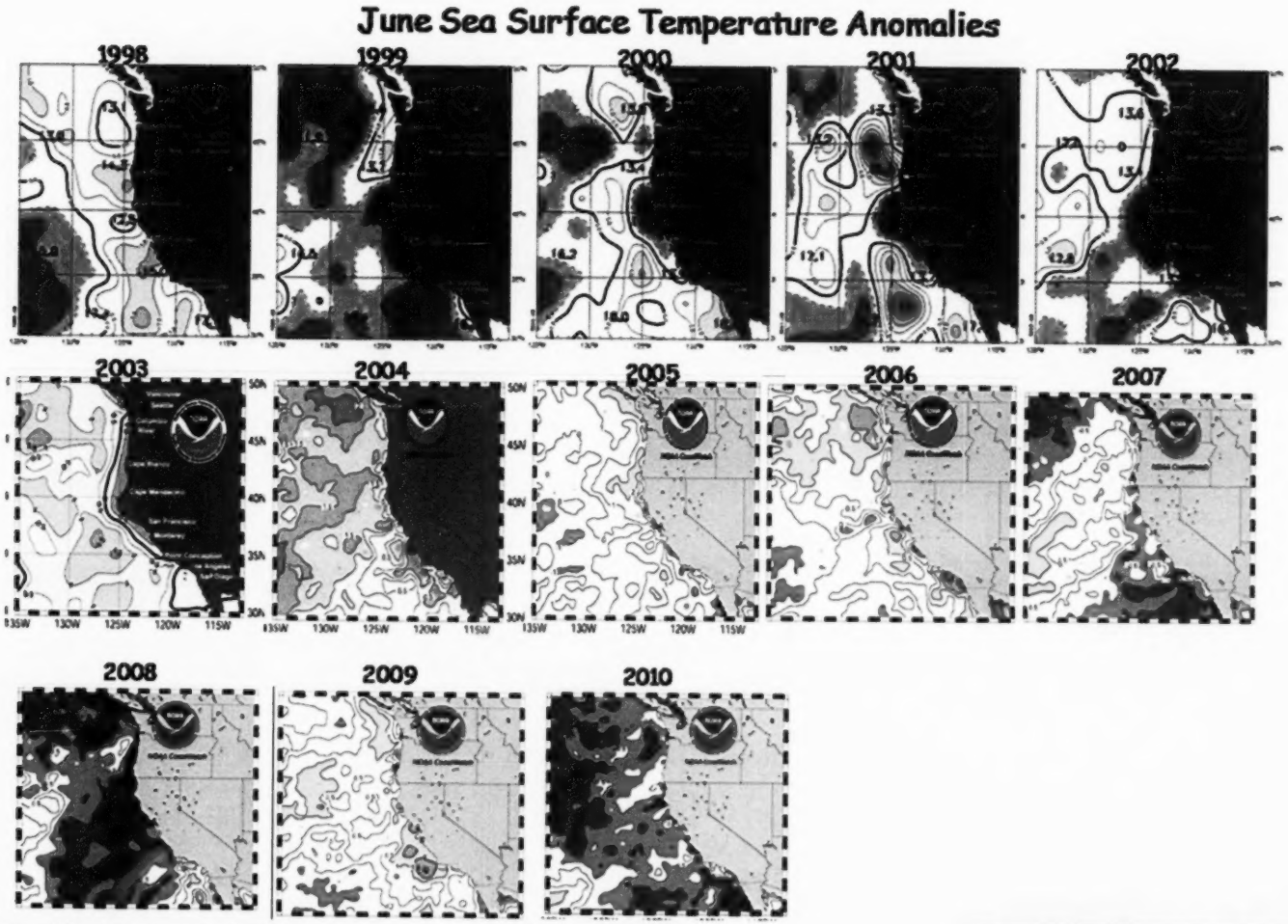


Figure 12. June sea surface temperature anomalies from 1998-2010.

CANADA

West Coast of Vancouver Island Summer Trawl Survey, 2010

L. Flostrand, J. Schweigert, J. Detering, V.Hodes, G. McFarlane

Survey Objectives: The summer west coast of Vancouver Island surface trawl survey is conducted to collect information on sardine: 1) distribution, 2) abundance, 3) size and age structure, and 4) species associations (including sardine diet and predation).

Summary Objectives: This report provides a brief update on observations of the 2010 WCVI trawl survey.

Activities: Summer surveys employing mid-water trawls towed in surface waters (≤ 30 m) have been conducted most years on the west coast of Vancouver Island (WCVI) from 1997 to 2010 to observe biological trends in sardine stocks related to regional distribution, abundance and species associations. The 2010 survey is the 9th directed at estimating sardine abundance in coastal waters off the WCVI.

This report summarizes a portion of the sardine data collected during a research cruise conducted from July 25 to August 5, 2010. The 2010 research cruise was carried out aboard the R/V W.E. Ricker. Fishing was done at night using a model 250/350/14 mid water rope trawl (Cantrawl Pacific Ltd., Richmond, British Columbia). Fish were measured for fork lengths, recorded to the nearest millimetre. Biological samples were also collected for sex, stomachs and otoliths (Table 3).

For assessing abundance, a new sampling protocol using pre-determined randomized trawl set locations was adopted in 2010 to minimize potential bias that may result from assuming line transects that are fixed within the survey region. The 2010 survey design was based on a 10 x 10 km grid extending approximately 2 to 52 km from shore with a range in latitude of 50.7-48.5° extending southward to10 km from the US border. The potential sampling stations were set at the intersections of the grid network. Across strata, assignment of sampling stations was done by applying proportional probabilities to possible stations so that each stratum would receive approximately equal sampling intensity. This was done based on the assumption that 75 coastal stations would be sampled. Biomass estimates were calculated using standardized estimates of catch density (mt/ km^3). Estimates of volume of water swept during a fishing set were determined by multiplying the length and width dimensions of the trawl net by the effective fishing distance covered during the set. For each stratum, the average catch density was multiplied by the estimated surface volume of the stratum to derive estimates of biomass (Table 3). The sum of these biomass estimates represents the total biomass in the survey region. Inlets were not included in the strata.

Table 3. Summary of biological samples taken onboard the W.E. Ricker July 25-August 5, 2010.

Sample Type	# of Sardines
Weight	2450
Length/Sex	2850
Length Frequency	1898
Stomach/diet	~ 625
Otolith/Age	750

In effect, 70 coastal stations were sampled along this grid and an additional 2 sets were made in Barkley Sound (Figure 13). Of the total 72 sets, 40 sets contained sardines but there was considerable variability in the distribution of catch densities across strata (Figure 13). No sardines were caught in the 13 most northward sets (north of Brooks Peninsula), which represents stations in Strata 1 and 2. Catch densities were highest in the three southern strata and mostly from sets relatively close to shore. For Strata 3-6, the proportions (and numbers) of sets with sardines are: 0.50 (8); 0.82 (14); 0.75 (9) and 0.60 (6), respectively. Based on catch weights and swept volumes, estimates of non-zero sardine densities for individual sets ranged from 0.023 to 2,951.03 mt/km^3. For Strata 3-6, estimates of average sardine catch density (mt/km^3) are: 52.8; 198.6; 260.7 and 195.4, respectively, which corresponds to biomass estimates of: 6,320.2; 16,663.4; 18,716.9 and 24,949.1 metric tons, respectively. The total estimate of sardine biomass in the coastal region represented by the stratified randomized survey design is 66,649.6 metric tons (Table 4).

Overall sardine fork length measurements from biological samples collected during the survey have two modal distributions, representing juveniles (age 1) and adults (ages 3 to 10), Figure 14). Juvenile sardines dominated the catch of a single set made offshore of Kyuquot Sound (Figure 13) and were found in low numbers in several other sets. The range in size of these smaller fish is 123 - 165 mm. All other sardine catches consisted predominately of adults (ages 3-10) with a size range of 176 to 288 mm.

Table 4. Pacific sardine west coast of Vancouver Island biomass estimates from night surface trawl surveys in 2006, 2008, 2009 and 2010. Volume estimates (km^3) can be converted to area estimates (km^2) by dividing by "0.03km", which represents average maximum depth of surface trawl and sardine distribution. No survey was conducted in 2007.

Year	Stratum	Area (km2)	Surface Volume (km3)	Mean Density (mt/km3)	Est Biomass (mt)
2006	2	2220.0	66.6	123.4	8,215.6
	3	3990.0	119.7	98.1	11,741.3
	4	2796.7	83.9	1,018.8	85,476.6
	5	2393.3	71.8	931.8	66,905.2
	6	4256.7	127.7	324.7	41,464.3
	All				**213,803.0**
2008	2	2220.0	66.6	120.6	8,028.8
	3	3990.0	119.7	1,065.7	127,569.0
	4	2796.7	83.9	469.8	39,412.4
	5	2393.3	71.8	2.8	200.8
	6	4256.7	127.7	114.7	14,641.3
	All				**189,852.3**
2009	2	2220.0	66.6	8.1	541.8
	3	3990.0	119.7	631.6	75,607.6
	4	2796.7	83.9	485.9	40,767.7
	5	2393.3	71.8	84.0	6,034.3
	6	4256.7	127.7	590.5	75,413.0
	All				**198,364.4**
2010	2	2220.0	66.6	0.0	0.0
	3	3990.0	119.7	52.8	6,320.2
	4	2796.7	83.9	198.6	16,663.4
	5	2393.3	71.8	260.7	18,716.9
	6	4256.7	127.7	195.4	24,949.1
	All				**66,649.6**

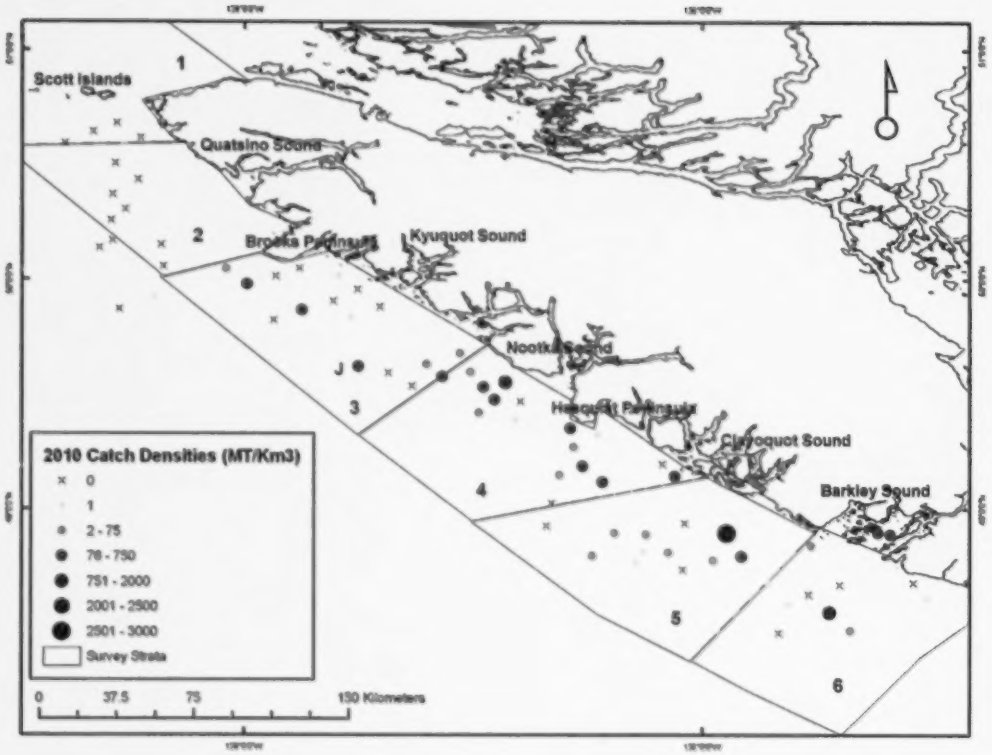


Figure 13. West coast of Vancouver Island set locations and approximate Pacific sardine catch densities for the night surface trawl survey, which occurred July 25 to August 5, 2010. Numbers 2 to 6 depict strata designation and the "J" in Stratum 3 indicates the set location which had predominately juvenile (age 1) sardines.

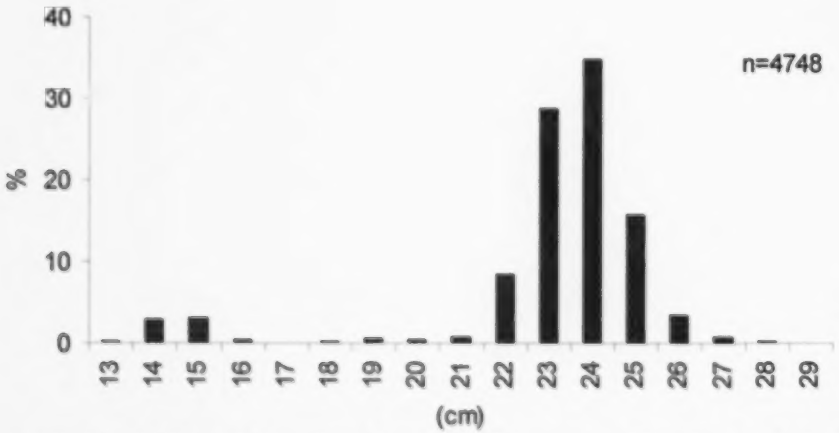


Figure 14. Pacific sardine fork length frequency from the 2010 survey off the WCVI, July 25 to August 5, 2010. Juvenile fish (13.0- 16.5 cm) are estimate to be approximately 1 year old and larger fish represent adults from 3-10 years old.

ABSTRACTS OF ORAL PRESENTATIONS

BAHIA MAGDELENA SARDINE FISHERY 2009-2010

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Centro Interdisciplinario de Ciencias Marinas Departamento de Pesquerías y Biología Marina Becarios COFAA y EDI

The sardine fishery in Bahia Magdalena has been shown a declining trend during last five years. Total landings in 2006 were 58,237 mt whereas in 2010 (January to August) landings decreased to 21,061 mt. During 2009, 530 fishing trips were carried out and 45,106 mt of small pelagic fishes were caught. In 2010, catch of the Pacific sardine (*Sardinops sagax*) was 36,338 mt, representing 92.8% of total catch. Other species landed included *Opisthonema* sp (3.7%), *Cetengraulis mysticetus* (2.9%), *Etrumeus teres* (0.2%) and *Scomber japonicus* (0.3%). Pacific sardine was caught throughout 2009 (except in December), although 81% of landings were from May to August and 73.6% of fishing trips were carried out at this time. Size of Pacific sardine ranged between 121-200 mm SL. Only 33.2% of sardines caught were above the minimum legal size (150 mm SL). Five age groups (0 to 4) were found, although age group 1 was the most abundant (78.4%). During January to August 2010, 21,061 mt of small pelagic fishes has been caught in 316 fishing trips. Pacific sardine catch was 8,172 mt and represented only 38.8% of total landings. Pacific sardine practically disappeared of Bahia Magdalena during ten months (September 2009-June 2010).Others species caught in these months of 2010 were *Opisthonema* spp with 4,960 mt (23.5%), 6,682 mt (31.7%) of *Etrumeus teres*, 387 mt (1.8%) of *Cetengraulis mysticetus*, and 860 mt of a mix of species (4.1%). Biological samples of Pacific sardine taken during 2010 haven't still been analyzed.

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2010 FOR U.S. MANAGEMENT IN 2011

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The Pacific sardine resource is assessed each year in support of the Pacific Fishery Management Council (PFMC) process that, in part, establishes an annual harvest guideline ('HG') for the U.S. fishery. The following assessment update for 2011 management is based on data sources and methodologies described in detail by Hill et al. 2009 and Jagielo et al. (2009), and reviewed by a STAR Panel during September 2009 (STAR 2009). In this update, we append fishery-dependent and survey series with more recently available information, without changes to base model structure or parameterization. A preliminary draft assessment was reviewed by the SSC's CPS-Subcommittee October 5-7, 2010, in La Jolla, California. Modifications to input data were incorporated during the course of that review, resulting in changes to population estimates and management-related quantities. The present report has been updated to reflect those changes.

Data and assessment: This assessment update was conducted using 'Stock Synthesis' version 3.03a and utilizes fishery and survey data collected from mid-1981 through mid-2010. The model uses a July-June 'model year', with two semester-based seasons per year (S1=Jul-Dec and S2=Jan-Jun). Fishery data include catch and biological samples for the fisheries off Ensenada, Southern California, Central California, and the Pacific Northwest. Two indices of relative abundance are included in the base model: Daily Egg Production Method and Total Egg Production estimates of spawning stock biomass (1986-2010), both based on annual surveys conducted off California. Finally, the 'tuned' update model '10w' was run with the addition of aerial (northern region) survey estimates of absolute abundance from 2009 and 2010 (q=1) to derive population quantities for 2011 management.

The update model '10w' had the following specifications, per Hill et al (2009):

- Model Year based on the July 1 birth date assumption (July 1-June 30 time span);
- Assessment years 1981-2010; Two semesters per year (S1=Jul-Dec; S2=Jan-Jun);
- Four fisheries (ENS, SCA, CCA, PNW), with annual selectivity patterns for ENS and PNW and seasonal selectivity patterns for SCA and CCA (S1 & S2).
- Use of length-frequency and conditional age-at-length data for all fisheries;
- Length-based, double-normal selectivity with time-blocking:
    - ENS, SCA_S1, & SCA_S2: 1981-91, 1992-98, 1999-10;
    - CCA_S1 & CCA_S2: 1981-92, 1993-98, 1999-10;
    - PNW: 1981-03, 2004-10;
- M = $0.4yr^{-1}$ for all ages and years;
- Time-varying growth in two periods: 1981-90 and 1991-10;
- Ricker stock-recruitment relationship; σ_R = 0.815; Steepness estimated;
- Initial recruitment (R_1) estimated; recruitment devs estimated from 1975 to 2008;
- Hybrid-F fishing mortality option;
- DEPM and TEP measures of spawning biomass (1986, 1987, 1993, 2003, 2004, and 2006-2009 for DEPM, and 1987, 1995-2002 and 2005 for TEP) and aerial survey estimates of abundance from 2009 and 2010.
- Length-frequency data for the 2009 and 2010 aerial surveys, taken from point-set samples, fit with a single selectivity function (double-normal, dome-shaped).

Stock biomass and recruitment: Stock biomass, used for determining the HG, is defined as the sum of the biomass for sardines ages 1 and older. Biomass increased rapidly through the 1980s and 1990s, peaking at 1.57 mmt in 2000. Biomass has subsequently trended downward to the present (July 1, 2010) level of 537,173 mt.

Recruitment was modeled using the Ricker stock-recruitment relationship. The estimate of steepness was high (h=2.253). Virgin recruitment (R0) was estimated at 4.62 billion age-0 fish for the base model. Recruitment increased rapidly through the mid-1990s, peaking at 17.156 billion fish in 1997, 19.743 billion in 1998, and 18.578 billion in 2003. Recruitments have been notably lower from 2006 to 2009.

http://www.pcouncil.org/wp-content/uploads/I2b_ATT2_ASSMT_UPDATE_NOV2010BB.pdf

REGIONAL ESTIMATES OF BIOMASS OF PACIFIC SARDINE IN 2010 AND RECENT YEARS

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This report updates time series of estimates of spawning biomass and biomass based on data collected during surveys on Pacific sardine conducted up to 2010 off the west coast of the American continent. These surveys are 1. Investigaciones Mexicanas de la Corriente de California (IMECOCAL) survey off Mexico, 2. April Daily egg production-California Current Ecosystem (CCE) coast wide survey from California to Washington boarder by the Southwest Fisheries Science Center, 3. The Northwest Fisheries Science Center (NWFSC) summer night time trawl survey near Columbia River and the Bonneville Power Administration (BPA) Columbia River plume study with day time trawls. 4. The NW aerial survey by the West Coast sardine industry and 5. Canadian West Coast Vancouver Island (WCVI) trawl survey. All NW surveys were conducted in the summer time except the CCE coast wide surveys which were conducted in both spring and summer when funding is available. Note, the spawning biomass from the IMECOCAL surveys are available only for years of 1997-2003. The NWFSC did not conduct their summer standard surveys in 2010 due to no fishing vessel bid on the contract for this field work. Yet, size/age data for May/June 2010 from plume and Columbia River estuary were collected.

Estimate of the spawning biomass of Pacific sardine off California in 2010 was 108,000mt compared to 180,000mt in 2009. Estimate of biomass off British Column was 67,000mt compared to 198,000mt in 2009. Estimate of biomass from the NW aerial survey was 201,000mt compared to 1.2 million mt in 2009. The preliminary estimate of biomass from the acoustic measurement taken during the 2010 April CCE survey was 350,000 mt compared to 0.8 million mt in April 2008. All four time series gave a strong signal that the population of Pacific sardine off US and Canada is declining. To understand the dynamic of the Pacific sardine off the west coast of the American continent, we need to asses the entire population of Pacific sardine and its relationship with the environment from BC to BC periodically.

PACIFIC SARDINE ABUNDANCE AND ASSOCIATED OCEANOGRAPHIC CONDITIONS OFF NORTHERN OREGON AND SOUTHERN WASHINGTON IN 2010

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Two fishery oceanographic surveys, which collect juvenile and adult sardines and measure environmental conditions off Washington/Oregon, were conducted in 2010. However, the Predator Survey, which has been conducted data annually since 1998, had severely reduced sampling because of the inability to contract a fishing vessel to conduct this research. As such we were unable to estimate biomass off the Columbia River in 2010. Some limited age analysis revealed that sardine did spawn successfully in 2009, probably because ocean temperatures were much warmer than 2008. Preliminary data indicate that sardine also successfully

spawned and recruited off the Pacific Northwest in 2010. However how this recent recruitment in the Northwest will influence future adult sardine abundance is presently uncertain.

PRELIMINARY RESULTS OF THE 2010 WEST COAST OF VANCOUVER ISLAND SARDINE TRAWL SURVEY AND THE COLLECTION OF AERIAL SURVEY DATA

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Summer surveys directed at collecting information on sardines off the WCVI started in 1997. Fishing is conducted in surface waters (≤ 30 m) using a mid water trawl towed at average speeds approximating 4-5 knots. Since 2006, sampling has been conducted at night. In 2010, the locations of stations were determined by randomly selecting sites along a 10x10km grid representing approximately equal sampling intensity in 4 zonal divisions of the region. The method of selecting stations in 2010 differed from past years in order to try to minimize potential bias associated with estimating biomass. In 2010, 70 sets representing an area of approximately of 17,000 km^2 were sampled. Forty of the 70 sets collected sardines, with many of the zero sardine hauls observed in the northern portion of the survey region. A preliminary estimate of ~ 70,000 metric tons was derived for the region using the method of expanding each stratum's average catch density (t/km^3) over an estimate of its spatial size (km^3) and then summing across strata. Juvenile sardines (age 1) dominated the catch of a single tow made offshore of Kyuquot Sound and were found in low numbers in several other sets. The range in size of these smaller fish is 123- 165 mm. All other sardine catches consisted predominately of adults (ages 3-10) with a size range of 176 to 288 mm (mean ~ 23 cm).

In 2009 and 2010, aerial survey trials were conducted to collect images representing sardine habitat with possible showings of schools. Results from these test trials will be aimed at evaluating technical parameters for possible future applications.

ERROR IN PACIFIC SARDINE ASSESSMENT ARISING FROM SPATIAL ASSUMPTIONS

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The results (and credibility) of stock assessments can be impacted by assumptions regarding spatial structure and movement. For the northern sub-population of Pacific sardine (*Sardinops sagax caerulea*), seasonal length-dependent migration has been described in the literature, as well as the possible presence of two stocks, rather than one. However, the current assessment, conducted using the Stock Synthesis 3 (SS3) framework, assumes a spatially-aggregated stock with constant growth across the entire coast and fleets with different selection patterns in the four areas included in the assessment (Ensenada, southern CA, northern CA and Pacific Northwest). We propose a simulation-based approach using an operating model including several hypothetical scenarios of spatial structure and seasonal movement, on which the performance of SS3 can be evaluated to determine (1) how much error can arise because assessments of sardine are conducted using a spatially-aggregated stock assessment method

when this assumption is violated, and (2) whether moving to a spatially-structured stock assessment could reduce this error. The focus of this presentation will be on working hypotheses and an introduction of the project.

THE 2010 CALIFORNIA CURRENT ECOSYSTEM SURVEY, SUMMARY AND COMPARISON TO PACIFIC SARDINE CAUGHT IN 2006 AND 2008 SPRING COASTWIDE SURVEYS

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Trawling during the April 2010 CCE survey covered a large area off the west coast of the U.S. from Cape Flattery, WA to San Diego, CA. Previous trawling was conducted off the whole west coast in the spring during 2006 and 2008 (Lo et al. 2007a, 2008). None of the 8 daytime trawls captured sardines while 18 of the 90 nighttime trawls contained sardines in 2010. We examined the range of sea temperatures at 3m depth, recorded during trawl operations, in three subareas off the coast: Washington and Oregon (9.5-11.4°C), northern CA (9.6-13.2°C), and the standard DEPM area (12.1-15.9°C). The 2010 temperature ranges were warmer than those during 2008, and while similar to the warmer temperatures in 2006 off Washington and Oregon, no eggs or adults were found in 2010. In all three surveys, sardines sampled were larger in the northern CA area, although much fewer in number, than in the standard DEPM area. In the standard DEPM area, sardine adults and eggs were always collected, and although the size of female sardines caught has increased from 67g in 2006 to 105g in 2008 and to 127g in 2010, the size of Region 1 (high sardine egg density) and P_0 (daily egg production) has decreased during this period of time. In addition the mean size of sardines (male and females) was slightly larger in 2010 (219 mm) than in 2008 (212 mm) and 2009 (211 mm), but there were very few sardines (0.9%) of sizes 175 mm to 194 mm SL compared to 2009 (8.6%) and 2008 (12.4%). These trends in the DEPM area coupled with the decrease in the spawning biomass since 2006 may indicate decreasing recruitment of recent year classes.

AN ACOUSTIC-TRAWL METHOD FPR SURVEYING EPIPELAGIC FISHES, AND BIOMASS ESTIMATES FOR THE DOMINANT SPECIES IN THE CALIFORNIA CURRENT ECOSYSTEM DURING 2006, 2008 AND 2010

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The abundances of epipelagic fish species in the California Current Ecosystem (CCE), from San Diego to Southern Vancouver Island, were estimated from combined acoustic and trawl sampling in the spring of 2006 and 2010, and summer of 2008. Pacific sardine, jack mackerel, and Pacific mackerel were the dominant coastal pelagic species (CPS). Anchovy and herring were sampled only sporadically. The estimates of Pacific sardine biomass compare well to those of the annual assessments and confirm that the stock has been declining since 2006. Concurrently, the biomass of jack mackerel has been increasing. The estimated biomass of Pacific mackerel is relatively low and variable. Future surveys of CPS in the CCE should benefit from: adaptive sampling based on modeled CPS habitat; increased acoustic and trawl sampling,

particularly of species with patchy distributions and low biomasses; and directed-trawl sampling for improved species identification and target strength estimation.

PREDICTING HABITAT FOR OPTIMIZING ACOUSTIC AND EGG SAMPLING OF PACIFIC SARDINE

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Prior to the collapse of the Pacific sardine fishery in the 1950s, the stock exhibited seasonal migrations which spanned the entire west coast of North America. The sardine routinely spawned off the Southern California Coast in the spring, and migrated northwards, as far as Canada, during the summer. During the subsequent decades of low abundance, however, the sardine appeared to remain in Southern California waters. When the stock increased in the 1990s, the seasonal migration pattern and the summer fishery off Oregon, Washington, and British Columbia were restored. The stock is assessed and managed using a catch-at-age model with fisheries independent abundance estimates from the Daily Egg Production Method and aerial surveys. In response to the Pacific Fishery Management Council's call for additional fishery-independent estimates of sardine biomass, the Southwest Fisheries Science Center began conducting acoustic-trawl surveys of sardine in the spring of 2006. To reduce the sampling error, the survey effort must be optimally applied to only potential sardine habitat. Presented here is a generalized-additive model of potential sardine habitat which is based solely on satellite-sensed oceanographic conditions. Described are the methods used for avoiding spatial auto-correlation in the data and selecting the most important environmental variables. The best model accurately predicts both the boundaries of the spawning stock during the spring-spawning season, and the spawning and non-spawning sardine during their summer migration. These predictions accurately match the annually-observed summer arrival of sardine off the mouth of the Columbia River, approximately 1000 km north of the main spawning area. Furthermore, the model predicts the historically-observed seasonal cycle of potential sardine habitat, and the summertime fishery off Oregon, Washington, Vancouver Island throughout the last decade. Quasi-real-time predictions of potential sardine habitat allow optimizations of survey time, place, and sampling effort.

TOO HOT OR TOO COLD? HOW PACIFIC SARDINE RESPOND TO TEMPERATURE FLUCTUATIONS

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Coastal pelagic fish species such as Pacific sardine (*Sardinops sagax*) undergo large fluctuations in abundance that end up affecting the marine ecosystems and the economies of countries worldwide. Climatic fluctuation has been suggested as a strong driver for these population booms and busts, but little work has been done to understand the effect of temperature on sardine physiology. In this study, our objective was to understand the optimal

physiological temperature range of Pacific sardine collected April-May off the southern California coast. These sardine likely represent the hypothesized "cold" stock of sardine. We subjected the sardine to slowly changing temperatures ranging from 9°C to 25°C. We sampled sardine at 9°, 11°, 13°, 15°, 17°, 19°, 21°, 23° and 25°C for blood plasma, heart, liver, and white muscle tissue. These tissues will be used to measure enzyme kinetics and gene expression of heat shock proteins and immune genes to identify an optimal temperature range for sardine. We will present preliminary results of specific activity and Michaelis-Menton constants of LDH in white muscle tissue, and gene expression levels of Hsp70 and Hsp90 in the liver. These preliminary results will provide insight as to how sardine respond to fluctuating temperatures and into their optimal temperature range.

RE-ASSESSMENT OF THE STOCK-RECRUIT AND TEMPERATURE-RECRUIT RELATIONSHIPS FOR PACIFIC SARDINE

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The harvest guideline for Pacific sardine (*Sardinops sagax*) incorporates an environmental parameter based on averaged surface temperatures at the Scripps Institution of Oceanography pier (SIO pier) in La Jolla, California, USA that would be invoked after a series of cool years to reduce commercial catches using a precautionary decision rule. We revisit the stock-recruit and temperature-recruit relationships underpinning the currently used environmental parameter for sardine assessment and found that the temperature-recruit relationship no longer holds for the SIO pier when time series are updated with data from more recent years. The significance of the correlation between temperature and recruitment was also artificially increased by autocorrelation in the time series. In contrast, the stock-recruit relationship was still valid when recent data were added. SIO pier surface temperatures are warmer than 10m-depth Southern California Bight (SCB) temperatures where the sardine spawn, and the difference has increased since the late 1970s. Sardine recruitment was also not related to offshore temperatures in the SCB. We demonstrate that the environmental proxy derived from SIO pier temperature, which has never affected the harvest guideline since its implementation, no longer predicts recruitment of Pacific sardine, and should be removed from sardine management.

TROPHICALLY-TRANSMITTED PARASITES AS BIOLOGICAL TAGS SUGGEST TWO MIGRATION PATTERNS OF PACIFIC SARDINES THROUGHOUT THE CALIFORNIA CURRENT SYSTEM

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We assessed the migration patterns of Pacific sardine (*Sardinops sajax*) within the California Current System (CCS) using trophically-transmitted parasites. Approximately 2500 sardines were collected from 2005 through 2008 between 50° to 31° North latitude, and 120° to 125° West longitude. We have examined parasite communities as well as population genetics of four parasite species. Among the twelve parasite species recovered from approximately 1500 sardines, two parasite species show strong potential as biological tags. The trematode

Lecithaster gibossus is prevalent in the parasite community of sardines caught in British Columbia waters, whereas the trematode *Myosaccium ecaude* is prevalent in sardines caught off California. Although Pacific sardines caught off Oregon and Washington can have either trematode, we found little overlap between the ranges of the two species and few individual sardines harbored both species. These results suggest limited migration throughout the expanse of the CCS. A comparison of the macroparasite communities of non-migratory northern anchovy (*Engraulis mordax*) collected off of Washington in 2007 and off southern California in 2008 supported *L. gibossus* as a biological tag from northern regions of the CCS. Results of population genetic studies of larval Anisakid nematodes and the trematode *M. ecaude* showed panmictic distributions with no regional differences. In summary, the examination of the parasite communities of Pacific sardine caught between 2005 and 2008 suggests two different migration patterns that overlap off of Oregon and Washington, but suggest little migration between southern California and British Columbia during those years.

FISHERY AND REPRODUCTION OF THE MONTERY SARDINE (Sardinops caeruleus) IN THE WEST COAST OF BAJA CALIFORNIA

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In Mexico, small pelagic fisheries (sardines, anchovy, mackerel), are the most important in landings (by weight). Fishery management requires knowledge about the reproductive biology of these species'. Random samples of sardines were taken from the landings of the commercial fleet in the west coast of Baja California for biometric data. Samples of gonad tissue were processed in the laboratory; and histological criteria were used to estimate the reproductive condition. A size frequency distribution was obtained and specimens ranged from 108 to 240 mm SL, with an average of 188 mm SL. The reproductive peak was identified in March, and smaller peaks occurred during June and December. The length at maturity was also estimated. We show and discuss features of the relationship between length at maturity, spawning seasonal, and temperature.

ABUNDANCE AND GROWTH RATE DURING EARLY LIFE STAGES OF PACIFIC SARDINE (Sardinops sagax) IN THE CALIFORNIA CURRENT ECOSYSTEMS

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Population growth of Pacific sardine *Sardinops sagax* results from successful recruitment, which depends on high growth and survival during the early life stages. We examined interannual variation in growth rate during larval and early juvenile stages of *S. sagax* by comparing daily growth increments in otoliths to population growth in the 1980s to 1990s off California. Archival otoliths of juvenile *S. sagax* (100 – 160 mm in standard length) archived by the California Department of Fish and Game were used for the growth analysis. Otolith increment width (IW), which varies with daily somatic growth rate, was measured for up to 150 days after hatching and

averaged during 30 d intervals from hatching. Mean IW during late larval stage (61-90 d) increased with the increase in recruit abundance in the 1990s. In contrast, mean IW during early juvenile stage (121-150 d) decreased in the 1990s and was negatively correlated with spawning stock biomass. This indicates that population growth of *S. sagax* in the early 1990s resulted from higher survival rates depending on faster growth rates during the late larval stage. Decrease in growth rate during the early juvenile stage in the late 1990s may be caused by density dependent effects, such as food limitation after onset of schooling and filter feeding.

THE EFFECT OF THE ENVIRONMENT ON CALIFORNIA'S COMMERCIAL FISHERIES

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Long-term, naturally occurring cycles can cause significant shifts in marine ecosystems referred to as "regime shifts". While the new regime can be as diverse and ecologically acceptable as that which it replaced, individual species may completely disappear or be greatly depressed when a regime shift occurs. In this work we examine an 80 year time series of California commercial fishery landings during which time the California current has been observed to shift from a warm to a cold then back to a warm regime. This period also captures the heyday of the U.S. Pacific sardine fishery in the 1930s, its collapse and its subsequent reemergence in the 1990s. We observe major changes in the species composition of commercial landings over this period and relate these changes to changes in the environment as expressed through changes in the forage base. Our initial findings suggest that while aggregate biomass may not be greatly affected by a regime shift, there can be significant changes in the operations of fisheries and in the economic value they generate.

THE VALUE OF FISHERIES ALONG THE CALIFORNIA CURRENT: A PREAMBLE TO ECONOMIC ANALYSES

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The fluctuations in the sardine stock associated with the California Current (CC) marine ecosystem can have important implications along its distribution area, both for the ecosystem and for fisheries, underlining the need to develop ecological and bioeconomic models that are dynamic and spatially explicit. In order to define their criteria and potential objectives, the system must be characterized in ecological and economic terms. We begin by identifying the main fisheries target groups that occur along the CC, along with their ecological linkages. We then present the economic value of the CC fish stocks to the countries that share this ecosystem. The goal of this contribution is to lay the foundation for ecosystem-economic models of the CC that will allow us to explore the outcomes of alternative ecological and management scenarios.

SARDINE, A FISHERMAN'S PERSPECTIVE

John Lenic
Canadian Pacific Sardine Association

The FAO technical guidelines for responsible fisheries states in section 4: Precautionary approach to fishery research, guideline 57 "*Recognizing that resource users have substantial knowledge of fisheries, a precautionary approach makes use of their experience in developing an understanding of the fishery and* its impacts." Pacific Sardines are unlike other pelagic species and as such may require a rethinking of traditional stock assessment methods. An understanding of the inherent characteristics of sardines may influence the protocol of assessment or even the fundamental understanding of the stock itself. Fishers have an intrinsic understanding of schooling behavior, seasonal variation in stock dynamics and the idiosyncrasies of the animal itself.

AN END-TO-END TROPHIC MODEL FOR THE NORTHERN CALIFORNIA CURRENT: INTER-ANNUAL VARIABILITY IN FOOD WEB STRUCTURE AND IMPACTS UPON PACIFIC SARDINE

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Hydrographic, plankton, seabird, and fish surveys conducted from 2003 - 2007 provide time-series data on pelagic community composition on the Oregon and Washington shelf. We synthesize this dataset into a series of independent, mass-balanced food web models from which we infer inter-annual changes in both direct and indirect top-down and bottom-up pressures acting upon Pacific sardine (*Sardinops sagax*). We next develop end-to-end models for the NCC as bottom-up transformations of the top-down balanced models built within the Ecopath platform. An end-to-end model maps the flow of production through the entire food web from the input of nutrients to the production of top predators and fisheries and back to recycled nutrients. The top-down Ecopath solution for the predation matrix (the consumption of each producer group by each higher trophic level consumer group) can be transformed mathematically to a bottom-up matrix as detailed in Steele, 2009 (J. Mar. Sys. 76: 186-194). In this study, we use end-to-end models to investigate the propagation of parameter uncertainty upwards through the web, analyze system sensitivity to variability in the strength of individual trophic linkages, and test the effects of alternate trophic linkage arrangements (scenario testing) upon Pacific sardine production.

POTENTIAL ECOLOGICAL PERFORMANCE INDICATORS FOR THE AUSTRALIAN SARDINE FISHERY

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The South Australian Sardine (*Sardinops sagax*) Fishery (SASF) was established in 1991 and is Australia's largest fishery by weight. Like all South Australian fisheries, the SASF is managed according to the principles of Ecologically Sustainable Development (ESD), which means that fisheries management decisions must balance ecological, economic, social and inter-generational equity considerations. Entry is limited to 14 licence holders. There are input controls, including limitations on net size. A Total Allowable Catch (TAC) is set annually and there are 14 equal Individual Transferable Quotas (ITQs). Industry takes a proactive role in management and other stakeholders are also involved. The costs of research, management and compliance are funded by industry through licence fees. The Management Plan identifies the biological, ecological, economic and social objectives of the SASF and outlines the framework of performance indicators, reference points and decision rules that has been established. Fishery-independent stock assessments are undertaken annually or biannually using the Daily Egg Production Method (DEPM). Stock assessments that utilise an age-structured population model are undertaken in years when fishery-independent surveys are not conducted. The baseline TAC of 30,000 t is maintained while estimates of spawning biomass remain between the limit reference points of 150,000 and 300,000 t (exploitation rates of 10-20%). Interactions with protected species have been assessed with through an independent observer program. An industry Code of Practice has been established to mitigate interactions with the short-beaked common dolphin (*Delphinus delphis*).

In 2004, an ecological study was initiated to: 1) assess the importance of sardine in the diets of key predators in the eastern Great Australian Bight (eGAB); 2) develop an ecosystem model for the region and 3) evaluate the potential for establishing ecological performance indicators for South Australian Sardine Fishery. The foraging patterns and reproductive biology of numerous pelagic fishes, squids, marine mammals and seabirds were examined. Catch data for the SASF was included in dietary analyses to facilitate comparison of the fishery with the consumption patterns of the 37 predator groups that were identified. The most important prey type in the eGAB was the Australian krill, followed by sardine, anchovy, Gould's squid and other crustaceans, which collectively accounted for 52.4% ± 21.4% of consumption. Eight guilds of predators were identified. The SASF was included in a guild with ten other predator groups that included several pelagic fishes (skipjack tuna, southern bluefin tuna, Australian salmon, snook, barracouta), the common dolphin and several seabirds (crested terns, Australian gannets, little penguins). This guild was defined mainly by the importance of sardine and anchovy in the diet and included the species that may be most likely to be affected by competition with the SASF.

Ecopath with Ecosim software was used to develop a trophic mass-balance model of the eGAB ecosystem. Four key parameters were estimated for each of 40 functional groups: diet, biomass, production per unit of biomass (P/B) and consumption per unit of biomass (Q/B). Data on landings, discards and effort for eleven fisheries (fleets) were included in the model. A time series of primary productivity data was also included. Model outputs suggested that significant changes occurred in the eGAB ecosystem between 1991 and 2008. These included a ~5 fold increase in total catch, which was entirely attributable to growth in the SASF, and a

corresponding reduction in the mean trophic level of the catch (mTLc). The biomass of several fishes, seals, dolphins and seabirds also increased through combined effects of reduced effort in other fisheries, and an increasing trend in primary productivity. The increase in Kemptons Q biodiversity over the study period shows that the rise in mLTc reflects the growth of the SASF rather than a reduction in high trophic level biomass relative to lower levels. The high Fishing in Balance (FIB) index suggested that current catch levels are not impairing ecosystem function.

Modelling indicated that many groups are sensitive to changes in sardine biomass, but sensitivity analyses based on mixed trophic impacts detected negligible fishery impacts on these groups, despite the fishery's rapid growth since 1991. Of the land-breeding marine predators, which may be the most tractable as EPIs, crested terns demonstrated the greatest sensitivity to reductions in sardine biomass both in direction (negative) and magnitude, followed by Australasian gannets and little penguins. Demographic studies have indicated that the offspring of the crested tern were smaller and had lower survival rates in years following two major sardine mass mortality events. This species appears to have the greatest potential as an ecological performance indicator for the SASF. The trophodynamic model developed in this study will be a critical tool for distinguishing the potential impacts of the SASF from those related to changes in other fisheries or in environmental conditions.

WORKING GROUP 1: REGIONAL BIOMASS RECOMMENDATIONS

1. A trawl gear comparison between Ricker and Frosti is planned for 2-5 days ship time in June-September, 2011.
2. An experiment on sardine tagging using the electronic acoustic receiver is planned in early June 2011 in Astoria to release fish in late fall. If possible, fish will be also tagged in San Diego in April. Fisher Ryan Kapp and Mike Okoniewski. are willing to contribute fish
3. Pursuit of the possibility of using the mid-water trawl used in Japan for juvenile sardine in future July surveys.

Sardine related meetings

1. In February, 2011, NMFS STAR panel for acoustic survey will be held and May star panel for LIDAR and satellite image surveys will be held.
2. Acoustic data from July-August trawl surveys off BC, 2009 was requested to be analyzed together with that of California Current Ecosystem (CCE) survey off California.

Summary of WG1 Regional Biomass Discussions

1. Comparison of US net trawling efforts and Canada net trawling efforts

We need to conduct a comparison/calibration between these efforts. We will try and do during June or September. During this time NOAA will have contract with FROSTI and should be able to carve out a couple of days to do side-by-side trawl efforts with RICKER. The big question is can the Canadians get similar times on the RICKER?

This would also provide an opportunity to look a comparison between acoustics (Sonar and EK60) and look at diel migration behaviour and if bottom mounted sonar can actually work in Canadian waters. Robert Emmett and Jake Schweigert will work on this.

2. Literature review of use of acoustics in the measurement of sardine populations.

Acoustics are used to assess pelagic fish populations all over the world but many of the Trinational Forum Participants are not aware of the literature regarding this application.
In February 2011 a STAR panel will be reviewing this Acoustic methodologies and the use of satellites to determine stock abundance of sardines. Hopefully the results of this STAR panel will provide a broad review of the literature. The result of this STAR panel will be presented at the 2011 Trinational Forum.

3. Acoustic Tagging of Sardines

The POST array now located off OR, WA, and Canada could provide valuable migration information if sardines could be tagged. A pilot study will be attempted in 2010 – to a) tag and hold sardines in aquaria and b) possibly release some tagged sardines.
Ryan Kapp has agreed to assist with sardine capture off Columbia River. Larry Robertson at SWFSC La Jolla lab will be contacted and see if he will have aquaria and sardines available for tagging. Robert Emmett will work on this in OR and Nancy Lo will coordinate in La Jolla.

4. Early Recruit Survey

Motomitsu Takahashi noted that in Japan they conduct an early recruit survey very successfully. They have been conducting this survey for the past 15 years. They sample the nursery grounds in May/June by specific mid-water trawl. Dr. Takahaishi will be sharing the specifics of the Japanese mid-water trawl and this survey with the Biomass Working group. Nancy Lo and Robert Emmett will follow up on this.

5. Use of Pacific Hake Acoustic Survey for Sardine Population Assessment

Every other year, NOAA/NMFS conducts an acoustic survey of Pacific Hake from Canada to southern California during June. This is also the time period when most sardine are on the shelf. These data may also incidentally capture acoustic information on sardine. David Demer has recently received some acoustic information from this survey and is in the process of analyzing if it can be used for sardine biomass estimates. He will report back at next meeting.

WORKING GROUP 2: STOCK STRUCTURE RECOMMENDATIONS

The stock structure working group focused their discussion on the migration of sardines. Traditional tagging experiments are not practical or effective methods to apply to sardines. Alternative studies are shedding light on migration patterns. Parasite studies have been helpful in building upon our knowledge of the sardine migration, however questions and uncertainties remain. Sharon Herzka is proceeding on track with her project using a micromill on otoliths should reveal information of birth locations. Furthermore, aerial and acoustic methods will further our understanding of migration. More sardines from offshore locations need to be collected to fill data gaps. A coast wide survey will be conducted in April 2011 and two surveys are scheduled for 2012 each in April and July. Thus, it is likely that every four years April-July coast wide surveys will be conducted.

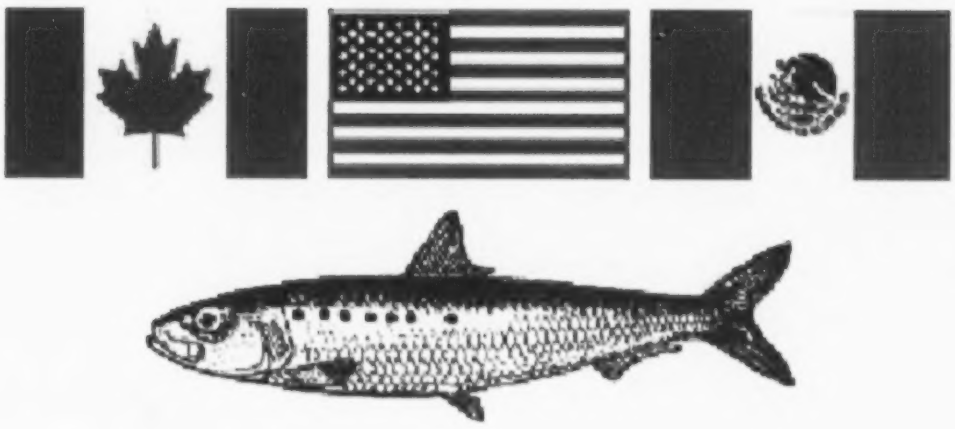
WORKING GROUP 3: INDUSTRY TRENDS, ISSUES AND RECOMMENDATIONS

The Industry Working Group reviewed the US and Canada economic situation. Central to the discussion was the impact of lower quotas on the industry. From the two countries' perspective the dominant issue was the need to improve the scientific assessments. This could be achieved by aerial assessments in the two fishing zones. This would require the BC trawl and aerial assessments to be included in the final US assessments. The two industries accept that they have a common interest in better abundance assessments in the Pacific Northwest. They will continue to work together on integrating the overflight data from the two countries.

APPENDIX A: AGENDA

TRINATIONAL SARDINE FORUM
FORO TRINACIONAL DE LA SARDINA
XI TH ANNUAL MEETING, 2010

AGENDA



Harbour Towers Hotel
Victoria, British Columbia, Canada
November 16-17, 2010 - Forum
November 18, 2010 – Workshop

MONDAY, NOVEMBER 15th

The Harbour Towers Hotel, *Vic's Steakhouse & Bar*

WELCOME GATHERING

18:00 - 21:00 Welcome Gathering at Vic's Steakhouse in the Harbour Towers Hotel
Early registration

TUESDAY, NOVEMBER 16th

The Harbour Towers Hotel, *West Harbour Ballroom*

08:00 **REGISTRATION**

09:00 **Opening Remarks**, *Jake Schweigert (DFO) and Nancy Lo (NMFS)*

WELCOME FROM SPECIAL GUESTS

09:05 Mr. Barron Carswell, Director, Oceans & Marine Fisheries, Ministry of Environment, Province of British Columbia

09:15 Dr. Laura Brown, Director, Marine Ecosystems Aquaculture Division, (DFO - PBS)

09:25 Meeting Logistics, *Linnea Flostrand (DFO)* and *Bernie White (Current Concepts)*

REGIONAL SARDINE FISHERIES REPORTS

09:30 Bahía Magdalena, *Kevin Hill (SWFSC)* on behalf of *Roberto Félix-Uraga, Felipe Neri Melo-Barrera, Casimiro Quiñonez-Velázquez y V.*, and *Daniel Hernández Valdez (CICIMAR)*

Gulf of California, *Information not available at this time*

Ensenada (N. Baja), *Information not available at this time*

9:50 California & Northwest, *Greg Krutzikowsky* (ODFW)

10:30 Canada, *Cynthia Johnson* (DFO)

10:50 **BREAK**

RESEARCH PLANS AND REPORTS

11:20 Biomass Estimation – General Introduction
Nancy Lo

11:25 Assessment of the Pacific sardine resource in 2010 for U.S. management in 2011
Kevin T. Hill, Nancy C. H. Lo, Beverly J. Macewicz, Paul R. Crone, and Roberto Felix-Uraga

11:45 Biomass estimates for the Northern Sardine Population *Nancy Lo*

12:05 **LUNCH**

13:30 Pacific Sardine Abundance and Associated Oceanographic Conditions Off Northern Oregon and Southern Washington in 2010.
Robert Emmett, Marisa Litz, Andrew Claiborne, and Paul Bentley

13:50 Preliminary results of the 2010 west coast Vancouver Island sardine trawl survey and the collection of aerial survey data
Linnea Flostrand, Jake Schweigert and Jackie Detering

14:10 Error in Pacific sardine assessment arising from spatial structure assumptions
Felipe Hurtado-Ferro, André E. Punt, and Kevin T. Hill

14:30 **BREAK**

15:00 The 2010 California Current Ecosystem survey, summary and comparison of Pacific sardine from 2006 and 2008 spring coastwide surveys.
Beverly J. Macewicz and D. A. Griffith

15:20 An acoustic-trawl method for surveying epipelagic fishes, and biomass estimates for the dominant species in the California Current Ecosystem during 2006, 2008, and 2010
Demer, D. A., Zwolinski, J. P., Byers, K. A., Cutter, G. R., Renfree, J. S., and Sessions, T. S.

15:40 Predicting habitat for optimizing acoustic and egg sampling of Pacific sardine
Juan P. Zwolinski, Robert L. Emmett, and David A. Demer

16:00 Too hot or too cold? How Pacific sardine respond to temperature fluctuations
Alena L. Pribyl, John Hyde, Russell Vetter

16:20 **ADJOURN**

18:00 **RECEPTION**

The Canoe Club, *450 Swift Street, Victoria, B.C.*
Welcome reception and dinner **(until ~ 21:00)**

WEDNESDAY, NOVEMBER 17th

The Harbour Towers Hotel, *West Harbour Ballroom*

RESEARCH PLANS AND REPORTS CONTINUED

08:30 Re-assessment of the stock-recruit and temperature-recruit relationships for Pacific sardine (*Sardinops sagax*)
Sam McClatchie, Ralf Goericke, Guillermo Auad, and Kevin Hill

08:50 Trophically-transmitted parasites as biological tags suggest two migration patterns of Pacific sardines (*Sardinops sagax*) throughout the California Current System
Kym Jacobson, Rebecca Baldwin, and Robert Emmett

09:10 Fishery and reproduction of the Monterey sardine *Sardinops caeruleus* in the West Coast of Baja California
Celia Eva Cotero Altamirano, Héctor Valles Ríos, and Brenda C. García Hernández

19:30 Abundance and growth rate during early life stages of Pacific sardine *Sardinops sagax* in the California Current ecosystems
Motomitsu Takahashi, David M. Checkley, Jr

09:50 **BREAK**

10:20 The Effect of the Environment on California's Commercial Fisheries
Samuel F. Herrick Jr., Jerrold Norton and Rognvaldur Hannesson

10:40 The value of fisheries along the California Current: a preamble to economic analyses.
Andrés M. Cisneros-Montemayor and U. Rashid Sumaila

11:00 Sardine, a fisherman's perspective
John Lenic

11:20 An End-to-End trophic model for the Northern California Current: inter-annual variability in food web structure and impacts upon Pacific sardine
James Ruzicka, Robert Emmett, Jeannette Zamon, Cheryl Morgan, Richard Brodeur, and Thomas Wainwright

11:40 **LUNCH**

13:00 Potential ecological performance indicators for the South Australian Sardine Fishery
Tim Ward, Simon Goldsworthy and Brad Page

13:20 The art of administering a sardine association
Don Pepper

WORKING GROUP DISCUSSIONS - CONCURRENT

13:40 WG 1: Regional biomass - *Nancy Lo*
WG 2: Stock structure, age structure and adult sampling – *Russ Vetter*
WG 3: Industry trends and issues – *Don Pepper*

14:40 **BREAK**

15:00 **PLENARY SESSIONS FOR REPORTING RESULTS OF WORKING GROUP DISCUSSIONS**

PS 1: Regional Biomass
PS 2: Stock Structure
PS 3: Industry Trends

16:00 **PLANNING FOR TSF 2011 AND CLOSING REMARKS**

16:30 **ADJOURNMENT**

APPENDIX B: LIST OF PARTICIPANTS

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APPENDIX C: WORKING GROUPS, CONTRIBUTORS AND COMMITTEES

WORKING GROUPS:
The principal goal of the working groups is to promote coast-wide cooperation in producing information needed regarding the biology and dynamics of the population:

WG1: Regional biomass - Nancy Lo
WG2: Stock structure, age structure and adult sampling - Russ Vetter
WG3: Industry trends and issues – Don Pepper

CONTRIBUTORS:
Canadian Pacific Sardine Association
Province of British Columbia
Canadian Department of Fisheries & Oceans

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Jackie Detering, Pacific Biological Station, DFO, Nanaimo, B.C.
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Linnea Flostrand, DFO
Jake Schweigert, DFO
Bernie White, Current Concepts
Sean MacConnachie, DFO

EXECUTIVE COMMITTEE:
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Sharon Herzka, CICESE
Robert Emmett, NOAA
Jake Schweigert, DFO

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Victoria, B.C.
www.HarbourTowers.com
Phone (from anywhere in North America): 1.800.663.5896
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APPENDIX D: ECOSYSTEM MODELING WORKSHOP

AGENDA

Workshop title: Workshop on Ecopath and Ecosim modeling of Pacific sardine in the California Current system

Location: Multimedia Room, Harbour Towers Hotel, Victoria, British Columbia, Canada

Co-convenors: Sandy McFarlane
Jake Schweigert

Background: At the last Tri-national Sardine Forum (La Paz, South Baja, Mexico, November 2009) a workshop was held to identify and plan steps to consolidate information on sardine prey and predators that could be used to develop an ecosystem model for the California Current System. Subsequently, meetings have occurred with scientists at the University of British Columbia in Vancouver to begin to develop an Ecopath/Ecosim model of this system. The 2010 workshop following the TSF will build on last year's meeting, by introducing an initial modelling approach and some of its preliminary results, and the workshop will encourage discussion of options for further model development and identification of model scenarios.

Agenda: Thursday, November 18th

09:00-09:15 Introductions

09:15-10:00 Workshop Overview and status report

10:00-10:15 **Break**

10:15-12:00 Ecopath/Ecosim model for southwest Vancouver Island.
Overview of the model and datasets
Review of the datasets and key species groups
Model scenarios.

12:00-13:30 **Lunch**

13:30-15:00 Discussion of how to game with the model
Run alternative model scenarios

15:00-15:30 **Break**

15:30-17:00 Planning for the Future
Outstanding data gaps and how to fill
Additional contacts
Future meetings

17:00 **Adjournment**

PROCEEDINGS

Workshop title: Workshop on Ecopath and Ecosim modeling of Pacific sardine in the California Current system

The recovery of the Pacific sardine (*Sardinops sagax*) and its expansion within the waters off Mexico, California, Oregon, Washington and Canada since the early 1980s, has stimulated renewed interest in understanding the factors which determine both increase in abundance and the change in distribution of the population. In an effort to better understand the role of sardines in the California Current System (CCS), participants of the Tri-national Sardine Forum have initiated the development of a tropho-dynamic ecosystem model. The goals of this project include; expanding our understanding of the inter-specific relationships in the CCS, exploring mechanisms underlying the expansion and contraction of sardine population(s), and ultimately predicting future changes in sardine abundance and distribution in the CCS.

At the Tri-national Sardine Workshop in 2009 in La Paz, participants agreed to move forward with the Ecopath with Ecosim (EWE) modelling tool. The first step has been to focus on the west coast of Vancouver Island, British Columbia, Canada. Species abundance, catch and effort, and diet data have been consolidated together with oceanographic indices and incorporated into an initial version of the model. University of British Columbia Ph.D. candidate Andrés Cisneros-Montemayor has been the key developer of this model.

At the 2010 Tri-national forum workshop, a detailed overview of the current version of the model was provided, highlighting some of the data gaps and potential additions to the model to include economic factors. He began by briefly comparing EWE with Atlantis and other ecosystem modelling platforms and then elaborated on the EwE roles of production, consumption and vulnerability terms and associated equations. Building on four main base models, the current model includes more than 30 functional species groupings and approximately 10 fishing fleets. Andres demonstrated some of the simulation options and resulting output to generate discussion among participants and a number of environmental drivers were considered. It was evident that the migratory behaviour of the sardine is an important aspect that must be accounted for in the model. There was discussion related to: 1) characterising different definitions of migration behaviour; 2) setting constraints on vulnerability functions; 3) modelling production associated with short term versus long term life stages; 4) spatial extent of representation; 5) applying information from single species models to increase sensitivity for balancing model (of production); 6) difficulties modelling seasonal effects; and 7) accepting model uncertainty for management purposes, especially at large scales.

Sandy McFarlane concluded the workshop discussion by outlining next steps, which include getting additional data on species diets, catches, and economic data to Andrés and the integration of economic data and appropriate environmental drivers and ultimately the extension to the entire California Current System for the development of a more complete WCVI Ecopath model for presentation at the 2011 Tri-national Forum.

APPENDIX E: ACRONYMS

CDFG	California Department of Fish and Game
CICESE	Centro de Investigación y de Educación Superior de Ensenada
CICIMAR	Centro Interdisciplinario de Ciencias Marinas
CONAPESCA	Comisión Nacional de Acuacultura y Pesca
CPSA	Canadian Pacific Sardine Association
CRIP	Centro Regional de Investigación Pesquera, Instituto Nacional de la Pesca
DFO	Department of Fisheries and Oceans, Canada
JIMAR	Joint Institute of Marine and Atmospheric Research
NWMFS	Northwest Fisheries Science Center, National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
PBS	Pacific Biological Station, Fisheries & Oceans
SIO	Scripps Institution of Oceanography, University of California San Diego
SWFSC	Southwest Fisheries Science Center, National Marine Fisheries Service
WDFW	Washington Department of Fish and Wildlife